1956

Competition between corn and weeds

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COMPETITION BETWEEN CORN AND WEEDS

by

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A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of

The Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Plant Ecology

Approved:

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In Charge of Major Work

Signature was redacted for privacy.

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Signature was redacted for privacy.

Dean of Graduate College

Iowa State College

1956

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LIST OF ABBREVIATIONS

a	Three normal cultivations
b	Three normal cultivations, two pounds pre-emergence spray
c	Second and third cultivations, two pounds pre-emergence spray
d	Third cultivation, two pounds pre-emergence spray
e	Cultivations if necessary, two pounds pre-emergence and one-half pound post-emergence spray at time of second or third cultivation (if necessary)
f	First and second cultivations, one-half pound post-emergence spray at time of third cultivation
g	First and third cultivations, one-half pound post-emergence spray at time of second cultivation
h	Second and third cultivations, one-half pound post-emergence spray at time of first cultivation
j	Three normal cultivations, two pounds post-emergence spray on ground after third cultivation
k	Three normal cultivations, sodiumethylsulfate five pounds per acre at the time of third cultivation
l	Three normal cultivations, hand-weeded
m	Cultivations if necessary, two pounds pre-emergence spray
ao	Three normal cultivations, one pound pre-emergence spray overall
as	Three normal cultivations, one pound pre-emergence spray applied in ten and one-half inch strips
bo	Second and third cultivations, one pound pre-emergence spray overall
bs	Second and third cultivations, one pound pre-emergence spray applied in ten and one-half inch strips
co	Third cultivation, one pound pre-emergence spray overall
cs	Third cultivation, one pound pre-emergence spray applied in ten and one-half inch strips

LIST OF ABBREVIATIONS (continued)

<u>do</u> Third cultivation, one pound pre-emergence spray overall

<u>ds</u> Third cultivation, one pound pre-emergence spray applied in ten and one-half inch strips

<u>eo</u> Three normal cultivations, two pounds pre-emergence spray overall

<u>es</u> Three normal cultivations, two pounds pre-emergence spray applied in ten and one-half inch strips

<u>fo</u> Second and third cultivations, two pounds pre-emergence spray overall

<u>fs</u> Second and third cultivations, two pounds pre-emergence spray applied in ten and one-half inch strips

<u>go</u> Third cultivation, two pounds pre-emergence spray overall

<u>gs</u> Third cultivation, two pounds pre-emergence spray applied in ten and one-half inch strips

<u>ho</u> No cultivation, two pounds pre-emergence spray overall

<u>hs</u> No cultivation, two pounds pre-emergence spray applied in ten and one-half inch strips

<u>jo</u> Three normal cultivations, no spray applied

<u>js</u> Three normal cultivations, no spray applied

<u>ko</u> Three normal cultivations, no spray applied

<u>ks</u> Three normal cultivations, no spray applied

<u>0-UW</u> No cross cultivation, check, not hand-weeded

<u>0-W</u> No cross cultivation and hand-weeded

<u>1-UW</u> One cross cultivation

<u>1-W</u> One cross cultivation and hand-weeded

<u>2-UW</u> Two lengthwise cultivations

<u>2-W</u> Two lengthwise cultivations and hand-weeded

LIST OF ABBREVIATIONS (continued)

2-UW	Two lengthwise cultivations and one cross cultivation
3-W	Two lengthwise cultivations and one cross cultivation and hand-weeded
2-S	Two cultivations, pre-emergence spray
2-SS	Two cultivations, pre-emergence spray, lay-by spray
3E-UW	Three cultivations with inside shovels
3F-UW	Three cultivations with outside shovels
P	Pigweed
F	Foxtail
M	Mixed weeds
C	Clean, hand-weeded
S	Three machine cultivations
C	One corn plant alone
A	One corn and 20 velvet-leaf plants
a	One corn and five velvet-leaf plants
S	One corn and 20 foxtail plants
s	One corn and five foxtail plants
F_1	Low fertility
F_2	High fertility
W_1	Low water level
W_2	High water level

INTRODUCTION

In the past quarter century there has been a steady decline in employment of farm practices on the basis of traditional methods or for appearances' sake. As the population and need for food have steadily increased, productivity of the crop has become the prime consideration in the evaluation of cultural methods. With the increase in dissemination of scientific knowledge has come a desire for methods based on scientific principles.

These general trends have resulted in a need for scientific investigation of many of the aspects of crop culture. Before the advent of chemical weed control, it was generally recognized that the operations of seed-bed preparation and cultivation were necessary primarily as a weed control measure. Improvement of weed control by chemical means may warrant the substitution of herbicide treatments for a greatly increased proportion of post-emergence cultivation practices. However each substitution must be evaluated on the basis of improved crop growth and yield. Results of limited evaluation studies in this respect are presented in this thesis.

The experimental work reported here was designed to compare the effectiveness of various new weed control methods with certain common practices in terms of corn yield. Observations of yield decrease due to root injury by close cross cultivation indicated that this aspect should also be investigated. The effectiveness of 2,4-D on broad-leaf weeds and its lack of effectiveness against the grasses at levels which are not injurious to corn revealed the need for investigation of the comparative competitive ability of these two classes of weeds.

Weed control methods of various types and intensities were employed. In 1950 and 1951 these included variations in the number of cultivations and in the number, method and rate of weed spray applications. In 1952 they were further supplemented to include observations on distance of shovels from the base of the corn plants to study the effect on the degree of injury to the roots. In four years of field experiments complete weed control by hand-weeding was employed, not as a practical weed control method, but as a control treatment to determine to what extent corn yields are reduced by the different degrees of weed infestation coupled with different methods and degrees of cultivation.

In 1953 in both field and greenhouse experiments an attempt was made to evaluate grasses as compared to broad-leaf weeds as competitors. Greenhouse experiments were conducted at two moisture levels and two nutrient levels, in which corn was grown alone and at two infestation rates with a grass and with a broad-leaf weed.

Some of the field experimental work reported here was conducted as a part of the farm machinery and chemical weed control studies of the Iowa Agricultural Experiment Station. The more laborious methods employed in an attempt to get at the specific factors involved in the competition between corn and weeds will be impracticable on a large scale farming basis. It is presumed, however, that this presentation and interpretation of data on corn-weed interactions under a wide range of conditions may prove to be of some value in the formulation of a sound program of weed control practices in corn production.

REVIEW OF LITERATURE

Plant Competition

Competition among plants is a widely observed phenomenon both in natural plant communities and in agricultural crops. It results when one or more factors of the environment become limiting to plant growth. Clements, Weaver and Hansen (3) divide competition into a) incidence, b) cumulation and c) outcome for the purpose of a more exact analysis. The incidence of competition occurs when the reaction of one plant limits the development of another. Cumulation acts to increase the initial advantage gained by a plant over its competitor. The ultimate outcome is dominance of one plant over another.

The fundamentals of competition have not as yet been established in a factor-wise manner and this will have to be done for the specific crops and weeds involved before a successful evaluation can be made of a given weed species as a crop inhibitor. Hodgson and Blackman (7) in their work on Vicia faba at various spacings measured some of the effects of competition for light, water and nitrogen. They found that stem length, branching and tillering depend on nitrogen and water supply available per plant. Shading from closer spacing was found to increase internode expansion and result in a taller, more spindly plant. Increases in population also diminished the number of nodes bearing inflorescences. Since the number of beans per pod and the size of the beans did not vary with the treatments, the number of pods formed was the primary correlant with yield. The production of pods was clearly shown to be dependent on the integrated effects of internal physiological factors and the external environmental conditions on the development of the plant.

Crop-Weed Competition

Among the first definite studies of competition in crop plants which sought to determine the effect of soil mass on yield were those made by Sachs in 1860 (19). In this experiment Sachs grew buckwheat in flowerpots, planting six seeds in some and 12 in others. Although rate of growth was equal at the outset, a difference soon developed; at maturity the two cultures were strikingly unlike. The open culture was characterized by large, vigorous plants with many branches, large deep-green leaves and many flowers. In the denser stand the stature was hardly a third as great, the habit pinched and the leaves small and pale.

Zoller in 1867 (27) showed with dwarf bean cultures that yield was very similar whether two, three, or four plants were grown in 3.5 liters of unfertilized soil. If the soil was fertilized the larger number of plants gave the greater yield. It was concluded that use of a large amount of seed was more profitable in fertile than in poor fields.

Wollney in 1881 (26) likewise found the yield to increase with the soil mass to a certain limit, progressively at first and then gradually diminishing. The more fertile the soil, the smaller the amount of seed needed for maximum yield. Increases of growth and consequent crowding brought about by more seed in a constant amount of soil caused a suppression of activities with its attendant ills. The shading brought about in dense stands affected the development of roots as well as fruit yields.

Hellriegel in 1883 (6) regarded field crops as shade plants to a certain degree because he considered light to be an important factor in their competition. Except for the early stage before the stand is closed and the last when it opens again through the death and drying of leaves, the individuals constantly shade and handicap one another.

Mayer in 1879 (13) agreed that space might be regarded as a production factor. Plants grown in small pots or too close to one another were handicapped as to absorption when compared to those with adequate space for development. Water and nutrients were recognized as critical factors.

Clements, et al (3) stated that in many crop areas water is the most important factor in competition. Minerals usually are next, with light a close third. In general there is a relatively greater reduction in light before it becomes critical than is true for water and minerals. The limiting factor may vary with the season and with the species. The latter is especially true between native and cultivated plants. When the entire crop or most of it is removed from the field each year, minerals often assume the paramount role in competition. This is particularly true in long-settled regions with humid climate where the amount of fertilizer needed is a fair measure of the relations between demand and supply of nutrients. However, views as to the exhaustion of the supply of minerals in the soil appear to be more-or-less incorrect since the longest series of experiments known, 75 years of continuous cropping without rotation or fertilizer, failed to reduce the average yield (5).

Crop and weed plants in the same field both made demands for moisture, light and nutrients (3). Weeds present competed for a limited supply of some of these factors and thereby reduced the development and yield of crop plants. Clements (2) noted that the century-long experiences of gardeners and farmers had shown that crowding was unfavorable to the best growth of crops, and consequently systems of sowing and planting have been evolved that have regulated density in such a manner as to secure the best yield with a minimum of seed.

The study of the relative importance of various weed species and their nutrient requirements is a field that has long been neglected. On arable land as well as on grassland, weeds are often found growing with cultivated plants. Often weeds constitute 30-50 per cent of the total dry matter production (24). The competition between these two groups of plants for light, moisture and nutrients is very severe since their demands often are similar. Many weeds can thrive and compete with crops under adverse conditions. This, together with the fact that often little is known about the growth habit and competitive behavior of the crop to be grown and the weeds to be destroyed, tends to complicate the weed problem.

Ecologically, the crop and weed plants may be considered as two rival communities. Two important differences are apparent in the competition among weeds and field crops as compared to competition among plants in natural communities. First, habitat is controlled to as large a degree as possible to favor the crop over the weeds; second, individuals of one species or variety of crop plant are planted as closely as practicable. Such characteristics as uniform plant height, leaf size and shape, ear size, shape and attachment level and date of maturity are examples which contribute to a good hybrid corn variety, for instance. Pavlychenko (15) on the basis of an 18-year study of the growth habits, seeds, top growth and root systems of crop and weed plants, emphasized the following conclusions: a) Competition for moisture, light and nutrients by weeds resulted in crop yield reduction. b) Field crop seeds were in general larger and capable of germinating from a greater depth, more rapidly, in higher percentages and at lower temperatures than the majority of broad-leaf weeds. c) Field crop plants possessed a stronger cuticle and more fibrous foliage and stems than most broad-leaf weeds. d) Grain crops grew more rapidly and developed larger root systems and assimilative leaf surfaces than the common weeds, including wild oats and darnel. e) These differences in biological characteristics between crop plants and weeds facilitated the use of specific production techniques favoring establishment of the crop.

Only a few references occur in the literature dealing specifically with weeds as important competitors for plant nutrients. The principal objective of the study of Vengris, et al (24) was to determine the chemical composition of field-collected weed species and also of their companion cultivated plants. Nitrogen and potassium are often limiting factors in crop production. Weeds are important competitors with cultivated plants for these nutrients. Considerable quantities of them were accumulated by the weeds at the expense of the cultivated plants. When these soil elements were not available in liberal quantities the result was a reduction in crop yield. Phosphorous was shown to accumulate in weeds in large amounts, indicating that this, too, is a factor in competition when quantities of available soil phosphorous are inadequate. These high phosphorous levels in weeds, on the other hand, in spite of low levels of available phosphorous in the soil, were taken to indicate that many weeds are capable of utilizing forms of soil phosphates which are relatively unavailable to many cultivated plants. Some plants release phosphorous that is not readily available in the soil. Vengris, et al (23) later showed that supplying the high phosphorous requirements of some weeds such as pigweed and lambs' quarters was responsible for their action as stronger competitors of corn at high soil phosphorous levels than at low ones.

As an example of extreme variation of nutrient responses of different plants, Pierre (17) discusses the response of corn and soybeans to soil fertility levels, and feels that as more is learned about the cultivation of soybeans, 40 bushels per acre yields might be obtained as easily as the 100 bushel yields commonly realized from corn. He stated that on soils of low productivity level, soybeans usually have an advantage over corn in yield. On soils of medium fertility, fertilizer additions produce nearly equal effect on both crops. At high fertility levels, corn may have the relative advantage in response to added nitrogen.

Available root space, water, light and nitrogen were limited and controlled in an investigation of competition among the weeds, *Spergula arvensis* and *Matricaria inodora*, and barley, carried out by Mann and Barnes (12). A definite density of plants per volume of soil was achieved by the barley or weeds when grown alone. When they were grown together an increase in the density of barley diminished the injurious effect of the weeds and the weight of both weeds decreased as the number of barley plants increased. Increases in numbers of either weed plant exceeded that of barley plants if the barley plants were weak; however, if the barley plants were strong, the production of both weeds was reduced. The effect seemed to be only one of competition for root space or for nitrogen where there was not an excess of the latter. Blackman and Templeman (1) found that the nature and effects of competition varied with weed species. Barley competing with Brassica arvensis was primarily reduced in number of tillers and shoots of barley whereas Raphanus raphanistrum seemed to have a later effect on stand and yield of this crop plant. Nitrogen manuring was found to counteract depressive effects of weed competition in the majority of cases. This may be more economical than weed suppression when competition is largely for nitrogen.

Roots developed at approximately the same rate on both Marquis wheat and wild oats when they were grown together, and both plants produced seed. Pavlychenko and Harrington (16), in summarizing the factors responsible for success in competition, list a) readiness and uniformity of germination under adverse moisture conditions, b) the ability to develop early in the seedling stage a large assimilation surface, c) possession of a large number of stomates and a root system with a large fiber mass close to the surface but with its main roots penetrating deeply. In order of competing ability, cereal crops were classified as follows: barley, rye, wheat, oats and flax. Weed-crop competition often begins below ground. Presence or absence of competing species often has a great influence on the total extent of roots of seedlings and mature plants. Natural distribution as well as extent are important in determining the competitive ability of a root system. Hannchen barley planted with wild oats showed a much more efficient development and distribution of roots with the result that the wild oats scarcely produced seed. Wild mustard developed roots about four times those of wild oats and practically prevented the development of fruit by the barley.

The need for weed eradication is emphasized by the increase in crop yield in response to clean cultivation by various methods (8). The drier and more unfavorable the climatic conditions the greater the need for effective weed control. Although weeds are frequently very numerous in the early seedling stage, they often totally disappear during the later part of the season leaving crops practically free of weeds at harvest. The amount of dry matter produced by weeds in relation to that of crop plants per unit area affords a much better criterion of damage than the number of weeds.

The same weeds were found by Pavlychenko (14) to react very differently under similar infestation, climatic and soil conditions when growing with different crops or if the latter were planted at different rates. Number and time of cultivations should be determined primarily by the appearance of weeds. Additional cultivations for the maintenance of surface mulch were found to have little if any effect on the yield. In fact, cultivation, if deep, destroyed many of the roots, and the crop plants were not able to utilize nutrients in this richest portion of the substratum (25). Cover crops or inter-cropping can be used to control the depth of rooting to a considerable extent.

Staniforth (22) in his study of plant competition between field corn and _Setaria spp._ found that the corn yield losses which may result depend largely upon the extent to which corn and weeds compete for moisture, nutrients and light. Variations in weed infestations as to size and length of time they competed with corn resulted in variation of the degree of competition for these factors (21). Conditions of corn production were varied as to the level of nitrogen fertilization and corn plant populations (22). Weed removal at corn emergence, eight to ten leaf emergence stage, two weeks before tasseling, at tassel emergence and at corn maturity produced contrasting effects during a heavy rainfall year as compared to a low rainfall year. During the high rainfall year the weed infestations averaged 500 pounds of dry matter per acre and caused relatively small corn yield reductions (six to eight bushels per acre) when left to maturity. This was true both in plots which received no nitrogen fertilizer and in plots which received 70 pounds per acre of nitrogen with 16,000 corn plants per acre. No appreciable corn yield reduction was observed with nitrogen applications of 140 pounds per acre, even when weeds were left until the corn matured. During the low rainfall year, fertilized weed free plots produced corn yields equal to those of the wet year. The 50 per cent heavier weed infestations (600-900 pounds per acre) resulted in much greater reductions of corn yield than those of similar infestation rates in the wet year. These reductions were large in many instances even when the weeds were removed in early July. The relation of weed losses to nitrogen level was similar to that in the wet year. Yield losses were greatest in low nitrogen plots and yields of corn as well as of weeds were highest in those that had been heavily fertilized (22).

In the progressive development and seasonal variations of the corn crop the effect of severe drought in stunting size and delaying silking which resulted in many partially or completely barren plants was reported (9). A severe moisture deficit during the fertilization period (18) reduced the size of the plants and the transpiration rate and thereby lowered the use of water. Water use likewise was reduced by being removed prior to maturity (9, 18) but was affected very little by its removal after maturity. There was a rather fixed interval of time of about seven to eight weeks between fertilization and cessation of translocation to the ear which is considered the mature stage. Drought following fertilization was observed to shorten the ears by drying back from the tip and reducing the kernel size because of destruction of protective tissue. After maturity the decrease in moisture progressed at a rather uniform rate until moisture of grain and cob reached values of 15-20 per cent. In a year of severe drought, two supplemental irrigations of three inches each were reported to have increased fodder yields from 2.11 to 5.72 tons per acre and grain yields from 0 to 72.4 bushels per acre.

Under conditions of low soil moisture, reduced yield and reduced response to nitrogen were reported by Krantz (10). Robins and Domingo (18) investigated the effect on yield and plant development of severe soil moisture deficits at specific growth stages of field corn. Depletion of moisture to the wilting percentage at certain physiological growth stages markedly depressed the grain yields. During the tasseling or pollination period such a deficit for a period of one to two days resulted in as much as 22 per cent reduction in yield. Periods of six to eight days gave a yield reduction of about 50 per cent. If available moisture was removed after fertilization the yield reduction appeared to be related to the maturity of the grain at the time that the water was removed. The most severe competition between weed and crop plants often centers around the supply of soil moisture available to the plants. This was indicated by comparing the root systems of the weed and crop plants. In many areas available soil moisture is the limiting factor in crop production (14). The depletion of available water after maturity of the grain had no effect on yield and did not influence the moisture content (17) of the grain, cob or stalk. It had little influence on the water content of the leaf.

Wherever crop and weed plants occur together some degree of competition is bound to exist. "Weed free" soil is very rare and if left without cultivation for any length of time even the most worthless crop land will probably be seeded by wind, insects or other natural means and the established, invading plant community will soon be expanded to such an extent as to utilize the resources present (14).

Godel (4), one of the pioneers in the field of chemical control of annual weeds, used copper nitrate, copper sulphate and sulphuric acid sprays with varying degrees of success. He recognized the variations in species susceptibility of both the weed and crop plants. He also pointed out that plants are more susceptible at certain stages in their development than at others. The possibility of an accumulation of copper in the soil producing a toxic effect was ruled out by experimental additions of very high amounts with no toxicity to the plant roots.

Growth habits of the plants are very important in designing, applying and evaluating weed control methods. The germination habits of weeds may affect their competitive ability. In a test by Pavlychenko (14) it was found that 73 per cent of a group of cereal seeds germinated in the first five days of the test while only 26.2 per cent of 12 weed species germinated. The crops approached the limit of their germination capacity during the next five days. The weeds continued to germinate slowly until the twenty-second day of the test. Because of this fact the crops produced a dense and uniform stand in a few days, thoroughly occupied the soil with their roots, covered the surface with top growth and left little chance of survival for the weeds which germinated at later dates. The extent of the assimilating leaf surface per individual plant at different stages of development is another factor which plays a part in determining the competitive efficiency of a species. A plant which has a large leaf surface with many stomates per unit area is capable of synthesizing plant foods at a greater rate and therefore grows much more rapidly than those with less leaf surface and fewer stomates. In the above experiment, at the five day stage the four cereals had a larger leaf surface than the five weed plants which had germinated. At the blooming stage all weeds had far surpassed the crops both in extent of leaf surface and in number of stomates per plant. From this it is apparent, at least in part, why weed plants may easily be smothered by a dense growth of cereal crop plants in the early stage of their development. However, if the weeds survive they may choke the crops later in the season (14).

Defective roots cause death of plants before they emerge above the surface (14). Plants with weak root systems live for some time but usually perish before maturity. Individuals with healthy and strong roots are the only ones able to produce a luxuriant top growth and mature fruit. In the early seedling stage the root systems of the crop plants were nearly equal in size or much greater than those of the weeds competing with them. As the season progressed the size of the root system of crop plants excavated from the competition plots gradually decreased in comparison with the controls. Competition with weeds reduced crop yields almost in exact proportion to the degree of reduction of the root systems.

METHODS AND PROCEDURE

General Outline

Research on the ecological phases of corn-weed competition was started in 1950 in the plots of the weed control project of the Iowa Agricultural Experiment Station. These experiments and others in 1951 were carried out at the Agricultural Engineering Farm located about four miles southwest of the college campus. In our studies quantitative data on growth of the plants under 12 weed control treatments were taken in 1950 and 1951 to obtain more information on the response of the plants to the treatments. A second series of experiments was conducted in 1951 chiefly to compare effects of overall spraying with those of strip spraying under 10 different applications of mechanical cultivation. Our chief objective was to compare the degree of competition and its effect on development of the crop and on the yield.

Additional experimental work was carried out in 1951 to observe more closely the effects of both cultivation and weed control without cultivation. The experiments were conducted at the Ash Avenue Botany Research Farm, located five blocks south of the Iowa State College campus. It included a set of hand-weeded plots and one set that was not hand-weeded. Each set was subdivided into portions to receive no cultivation and one, two and three cultivations, respectively. In 1952 these Ash Avenue experiments were repeated but expanded to include two spray treatments for weed control and two additional treatments to investigate the injury to corn roots caused by cultivator sweeps passing too close to the plants and injuring the roots.

In 1953, further work was done at the Earl Hackbarth farm, four and one-half miles east of Dows, Iowa, to compare the broad-leaf and grass weeds in their effectiveness as competitors with corn. A series of plots of corn was set up with only _Setaria spp._, foxtail, as a competitor and another series with only _Amaranthus spp._, pigweed. Mixtures of the two weeds, hand-weeded plots and three mechanical cultivations rounded out these experiments.

Greenhouse experiments were conducted in the winter of 1953-4 to study the nature and degree of competition between corn and a broad-leaf weed, _Abutilon theophrasti_ Medic., velvet-leaf; and between corn and a grass weed, _Setaria glauca_ (L.) Beauv., foxtail. High and low levels of infestation of the two weeds, high and low fertility levels and high and low moisture levels were maintained.

Weed Control Machinery Experiments

The plot arrangement and key to weed control treatments of the 1950 field experiments, Field D-2 at the Agricultural Engineering Farm, are presented in Figure 1. The study was made to ascertain the possibility of utilizing herbicide applications to replace mechanical cultivations in the control of weeds. Adverse conditions at planting time were responsible for the elimination of the treatments on _m_ plots, resulting in two check plots, _m_ and _a_. The cultivation treatments at various rates were such that they

	north				
28'	Block I	II	III	IV	
147'	d c g f m k e b a l h j	c b h f m g d l a e j k	j e m d k l b g a c f h	a j h d b c l g m e f k	42 rows
28'	VIII	VII	VI	V	
147'	a f m e h j d c l b k g	g d l h j b c f m a e k	g h a c f j m l b e d k	b a l g c h m f j e d k	42 rows
28'					
	south				

Treatments

Plot	Pounds 2,4-D acid per acre: Pre-emergence	Pounds 2,4-D acid per acre: Post-emergence	Time of spray	Cultivation	Miscellaneous
a				3 normal	
b	2		As convenient	3 normal	
c	2		" "	2 (miss 1st)	
d	2		" "	1 (miss 1st & 2nd)	
e	2	1/2	2nd or 3rd cult. dependent on weed growth	If necessary	Post-emergence spray date determined by observation
f		1/2	3rd cult. time	1st & 2nd	
g		1/2	2nd cult. time	1st & 3rd	
h		1/2	1st cult. time	2nd & 3rd	
j		2	After 3rd cult.	3 normal	Spray on ground
k			3rd cult. time	3 normal	Sodiumethylsulfate 5#/A
l				3 normal	Hand-weeded
m	2			*If necessary	List corn

*Received 3 normal cultivations = a.

Figure 1. Plot arrangement of 1950 weed control experiments, field D-2.

left varying amounts of weeds competing with the corn crop. This gave an opportunity to observe the effects of competition on the growth of the plants and on the yields. In 1951 the same treatments were employed in field D as had been used in field D-2 in 1950, except for a re-randomization of the treatments within the blocks (Figure 2).

Field F-2 at the Agricultural Engineering Farm in 1951, was devoted to a comparison of strip spraying and overall spraying as a pre-emergence treatment. The treatments included the application of 2,4-dichlorophenoxyacetic acid amine at rates of one pound and two pounds per acre to various combinations of no, first, second, and third cultivations, sodiumethylsulfate at a rate of five pounds per acre along with three normal cultivations and check plots with three normal cultivations (Figure 3).

Competition Field Experiments

The experimental work at Ash Avenue Botany Research Farm in 1951 consisted of eight replicates of eight treatments, each of which contained a set of 5 x 5 hill plots (Figure 4). Only the plants in a 3 x 3 hill plot in the center of each were measured and harvested. The soil was near field capacity and had been prepared the day before planting. The seed used was Iowa hybrid 4318. Hand planters were used on May 15 to place five kernels per hill at 40 inch intervals in rows spaced 42 inches apart. Each hill was thinned to three plants shortly after emergence. The first and third cultivations were applied from east to west with a two-row, tractor-mounted cultivator equipped with sweep shovels. The second cultivation was applied

north

35'	Block I	II	III	IV	
147'	d f h l j m k e a g c b	f e c l j h d g a k b m	b k j d m g e h a f l e	e a k f m h g d j c l b	42 rows
35'	VIII	VII	VI	V	
147'	a l j k c b d f g e m h	h d g e b e f l j a k m	h c a f l b j g e k d m	e a g h f c j l b k d m	42 rows
35'					

south

Treatments

Plot	Pounds 2,4-D acid per acre: Pre-emergence	Pounds 2,4-D acid per acre: Post-emergence	Time of spray	Cultivation	Miscellaneous
a				3 normal	
b	2		As convenient	3 normal	
c	2		" "	2 (miss 1st)	
d	2		" "	1 (miss 1st & 2nd)	
e	2	1/2	2nd or 3rd cult. dependent on weed growth	If necessary	Post-emergence spray date determined by observation
f		1/2	3rd cult. time	1st & 2nd	
g		1/2	2nd cult. time	1st & 3rd	
h		1/2	1st cult. time	2nd & 3rd	
j		2	After 3rd cult.	3 normal	Spray on ground
k			3rd cult. time	3 normal	Sodiumethylsulfate 4#/A
l				3 normal	Hand-weeded
m	2				

Figure 2. Plot arrangement of 1951 weed control experiments, field D.

south

35'	Block I										Block II										Block III									
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	42 rows
140'	c	k	h	e	a	j	b	d	f	g	a	b	f	e	j	c	h	d	g	k	e	d	g	f	h	k	b	j	c	a	
	os	so	so	os	os	os	os	so	so	so	so	os	so	so	os	os	os	os	os	os	os	so	so	so	so	so	so	so	so	os	

35'	Block IV										Block V										Block VI									
	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	42 rows
140'	c	f	h	k	g	j	b	e	d	a	d	a	f	e	c	b	g	k	j	h	d	e	k	c	b	j	f	h	a	g	
	os	os	os	so	so	os	so	so	os	so	so	so	so	os	os	so	so	os	so	os	so	os	os	so	os	os	so	so	so	so	

35'

north

Treatments

Plot	Pounds 2,4-D acid per acre pre-emergence	Cultivation	Spray application
a	1	3 normal	
b	1	2nd & 3rd	
c	1	3rd	o-spraying overall or giving complete coverage (4 rows)
d	1	3rd	
e	2	3 normal	
f	2	2nd & 3rd	s-spraying in 10½" strips directly over the row (4 rows)
g	2	3rd	
h	2	none	
j		3 normal	
k		3 normal	

Figure 3. Plot arrangement of 1951 weed control experiments, field F.

north

C	2W	3UW	2UW	3W	2UW	3UW	3W	2W	3W	3UW	2UW	2W	2UW	3W	3UW	2W
NC	OUW	OW	1W	1UW	1W	OUW	1UW	OW	1W	OUW	OW	1UW	1W	OUW	OW	1UW
C	3UW	2UW	2W	3W	2UW	2W	3UW	3W	3W	3UW	2UW	2W	2W	2UW	3UW	3W
NC	OUW	1W	1UW	OW	1UW	OUW	1W	OW	1UW	OUW	OW	1UW	1W	OW	1W	OUW

south

Treatments

C: two lengthwise cultivations
NC: no cultivation

<u>In NC ranges</u>:
- 0-UW: no cross cultivation
- 0-W : no cross cultivation and hand-weeded
- 1-UW: one cross cultivation
- 1-W : one cross cultivation and hand-weeded

<u>In C ranges</u>:
- 2-UW: two lengthwise cultivations
- 2-W : two lengthwise cultivations and hand-weeded
- 3-UW: two lengthwise cultivations and one cross cultivation
- 3-W : two lengthwise cultivations and one cross cultivation and hand-weeded

Figure 4. Plot arrangement of 1951 competition experiments.

at right angles to the above and with a hand plow to approximate as closely as possible the type of cultivation applied with power equipment. For weed removal without disturbance of the soil, hand-weeding and very shallow cutting with a hoe were used. All of the plots of this hand-weeded set were kept free of weeds throughout the season.

Height, basal diameters (largest and smallest for each stalk) and number of leaves per plant were recorded for two randomly selected hills in each of the inner 3 x 3 hill plots at intervals of approximately 10 days from emergence until time of harvest. Yield weights were determined separately for the two hills on which growth records had been kept and then for the entire plot of nine hills. They included weight of the grain at harvest, stalks and weeds, calculated weight of grain at 14.5 per cent moisture content (market percentage), and of stalks and weeds at 14.5 per cent moisture for comparison.

The Ash Avenue Botany Research Farm experiments were expanded in 1952 to investigate the effect of root injury from cultivation. The seed used was of a long-season corn, Iowa hybrid 9385. The four replicates consisting of 12 treatments were arranged in such a manner that the standard machine treatments were contained in the northern tier, the hand and modified machine treatments in the middle tier and the chemical weed control treatments in the southern tier of plots. Various cultivation treatments were supplemented by hand-weeding (Figure 5). One of a pair of treatments in the modified machine section was carried out by removing the sweep of each gang closest to the row of corn. The other consisted of removal of the sweep farthest from the corn plants. This resulted in an uncultivated

north

3-W	3-UW	1-W	2-W	3-W	1-W	3-UW	2-W	1-W	3-W	2-W	3-UW	1-W	3-UW	3-W	2-W
3F-UW	3E-UW	0-UW	0-W	0-UW	0-W	3F-UW	3E-UW	3F-UW	3E-UW	0-W	0-UW	3E-UW	0-W	0-UW	3F-UW
2-UW	2-W	2-SS	2-S	2-UW	2-W	2-SS	2-S	2-UW	2-W	2-SS	2-S	2-W	2-UW	2-SS	2-S

south

Treatments

0-UW: Check, no cultivation, not hand-weeded
0-W : Hand-weeded, no cultivation
1-W : Hand-weeded, 1 cultivation
2-S : Pre-emergence spray, 2 cultivations
2-SS: Pre-emergence spray, lay-by spray, 2 cultivations
2-UW: 2 cultivations
2-W : Hand-weeded, 2 cultivations
3E-UW: 3 cultivations with inside shovels
3F-UW: 3 cultivations with outside shovels
3-UW: 3 cultivations
3-W : 3 cultivations, hand-weeded

Figure 5. Plot arrangement of 1952 competition experiments.

strip approximately seven inches wide on each side of the row in the first treatment and of a 14 inch, uncultivated strip midway between the two rows in the second treatment. Chemical weed control was also studied in 1952 by applying a pre-emergence spray of 2,4-D at the rate of two pounds per acre in one treatment and in addition to this pre-emergence application a late spray application at the same rate on another plot. Yield data were collected in 1952 in the same manner as they had been in 1951.

In the summer of 1953, field experiments to compare broad-leaf and grass weed competition with corn were set up on the Earl Hackbarth farm near Dows (Figure 6). Nine experimental plots were divided into weed-infested and hand-weeded sub-plots. Three of the sub-plots were infested with foxtail, three with pigweed and three with a mixture of the two weeds.

The field used for this experiment was one which had been in corn in 1952 and in clover pasture the preceding years. The soil was Clarion loam of high fertility, supplemented by the legume of the years previous and application of 5-20-20 fertilizer at the rate of 100 pounds per acre with planter attachment at the time the corn was planted. Adjoining fields were all prepared and planted in exactly the same manner but were machine cultivated through the growing season. The seed-bed was prepared during the first week in May, and the corn was planted on May 8.

Basal diameter, extended leaf height and number of fully extended leaves were measured at intervals throughout the growing season. At the time of harvest, yield data also were obtained from the machine cultivated corn fields immediately adjacent to each of these paired plots. As in the Ash Avenue experiments, the yields were determined for the individual hills

north

S	S	S	S
S	C	P	S
S	C	P	S
	C	M	
	C	F	
S	C	F	
S	S	S	S
S	C	F	
	C	P	
S	C	M	S
S	C	M	S
S	S	S	S

south

P: Pigweed M: Mixed weeds C: Clean, hand-weeded
F: Foxtail S: 3 machine cultivations

Figure 6. Plot arrangement of 1953 grass vs. broad-leaf weed competition experiments.

on which growth records had been kept as well as for entire plots. These data included grain yield, stalk yield and weed yield from an area equivalent to that occupied by two hills of corn (42 inches x 80 inches). The amount of dry matter per acre was determined in each case and from this the corn yield in bushels per acre at 14.5 per cent moisture level, corn-stalk ratio and weed yield in pounds per acre were calculated.

Competition Factor Experiments

Greenhouse experiments were carried out in the winter of 1953-4 to study the difference in nature and degree of competition between corn and a broad-leaf weed, Abutilon theophrasti Medic., velvet-leaf, and between corn and a grass weed, Setaria glauca (L.) Beauv., foxtail. The investigation included the two species competing with a corn plant separately at a high and a low infestation rate. Each of these experimental procedures was carried out at a high and low fertility and at a high and low moisture level. Including the controls at each fertility and moisture level without weeds, this gave a total of 20 different variations of environmental conditions under which to observe the corn plant.

Sandy loam soil in the amount of 5000 grams was placed in each one-gallon, glazed crock. Of the 100 crocks used, 50 were left at low fertility and 50 were treated with 5-10-10 fertilizer at the rate of 1000 pounds per acre. Half of each of these groups were maintained at a high moisture level, about field capacity, and half at a low moisture level, below field capacity, but above wilting percentage. Each of the five replicates consisted of a control corn plant, a corn plant with five foxtail plants, a corn plant with 20 foxtail plants, a corn plant with five velvet-leaf plants and a corn plant with 20 velvet-leaf plants at each of the four possible combinations of high and low fertility and high and low moisture levels. The components of the five replicates were re-randomized periodically in their positions on the greenhouse benches. The arrangement at the conclusion of the experiments is diagrammed in Figure 7.

Artificial lighting of an approximate intensity of 200 foot-candles was provided, with overhead lamps and automatic timers, to supplement the hours of daylight and extend the day to 15 hours, simulating summer growing season day length conditions.

Accurate observations and records were kept during the experiments including volume of water necessary to maintain the desired moisture levels, basal diameters of the corn plants, heights of the corn plants, heights of the weed plants, and finally fresh and dry weight yields of the tops and roots of corn and weed plants.

Replicate				
I	$F_1\ W_2$	$F_1\ W_1$	$F_2\ W_1$	$F_2\ W_2$
	A	C	s	C
	C	s	S	A
	a	a	a	a
	S	A	C	S
	s	S	A	s
II	$F_2\ W_2$	$F_2\ W_1$	$F_1\ W_2$	$F_1\ W_1$
	S	A	A	s
	a	C	a	C
	s	S	C	a
	A	s	S	S
	C	a	s	A
III	$F_1\ W_1$	$F_2\ W_1$	$F_2\ W_2$	$F_1\ W_2$
	s	S	C	s
	a	C	S	S
	S	a	A	A
	C	A	a	C
	A	s	s	a
IV	$F_1\ W_1$	$F_2\ W_2$	$F_2\ W_1$	$F_1\ W_2$
	S	a	C	C
	a	C	a	A
	s	A	s	s
	A	s	S	S
	C	S	A	a
V	$F_1\ W_2$	$F_2\ W_1$	$F_2\ W_2$	$F_1\ W_1$
	C	A	s	S
	a	a	a	C
	S	S	A	a
	A	s	C	s
	s	C	S	A

C - 1 corn plant alone
a - 1 corn & 5 velvet-leaf plants
s - 1 corn & 5 foxtail plants
F_2 - high fertility
A - 1 corn & 20 velvet-leaf plants
S - 1 corn & 20 foxtail plants
F_1 - low fertility
W_1 - low water level
W_2 - high water level

Figure 7. Competition factor experiments. Greenhouse bench diagram showing arrangement of treatments.

PRESENTATION OF EXPERIMENTAL DATA

Weed Control Machinery Experiments

Agricultural Engineering Farm studies

1950 experiments. The experimental work carried out in field D-2 at the Agricultural Engineering Farm was according to the descriptions given in Figure 1, except that adverse weather conditions at planting time made it necessary to eliminate the treatment on the *m* plots and as a result *m* and *a* are both check plots. Variations in weather conditions were determined for each group of field experiments. These data are presented with the plant response data of each group of experiments because these variations affect the final growth response results.

Records obtained at the official Weather Bureau Observation Station for Ames, Iowa, which is located at the Iowa State College Agronomy Farm, are presented here in Tables 1 and 2. This station is located one-half mile north of field D-2. Table 1 is a record of the rainfall: observed, normal and departure from the normal. The 1950 precipitation pattern was quite different from the normal as can be deduced from the negative and positive deviations from the normal. Heavy rainfall during May and June with below normal rainfall the rest of the year characterized this pattern. These weather variations must be considered as we evaluate the crop reactions to weed control methods and competition.

The average monthly temperatures and departures from the normal show

Table 1. Precipitation observed at the Agronomy Farm, Ames, Iowa, 1950

Month	Rainfall		Departure from normal	Accumulated departure from normal	
	Observed	Normal		Entire year	Growing season
January	1.07	0.87	0.20	0.20	
February	1.29	0.98	0.31	0.51	
March	0.53	1.43	-0.90	-0.39	
April	1.40	2.61	-1.21	-1.60	-1.21
May	7.14	4.18	2.96	1.36	1.75
June	7.55	4.34	3.21	4.57	4.96
July	1.92	3.42	-1.50	3.07	3.46
August	1.79	3.70	-1.91	1.56	1.55
September	1.22	4.28	-3.06	1.90	0.51
October	1.39	2.38	-0.99	-2.89	-2.50
November	0.30	1.51	-1.21	-4.10	
December	0.36	1.05	-0.69	-4.79	
Totals	25.96	30.75	-4.79	-4.79	-2.50

Table 2. Average temperature observed at the Agronomy Farm, Ames, Iowa, 1950

Month	Average temperature Observed °F.	Average temperature Normal °F.	Departure from normal °F.
January	18.4	19.9	-1.5
February	21.6	22.8	-1.2
March	31.1	35.9	-4.8
April	43.2	49.0	-5.8
May	59.7	60.6	-0.9
June	68.2	69.6	-1.8
July	69.5	74.9	-5.4
August	67.9	72.4	-4.5
September	63.9	64.4	-1.3
October	58.1	52.6	5.5
November	33.1	37.6	-4.5
December	18.8	24.4	-5.6

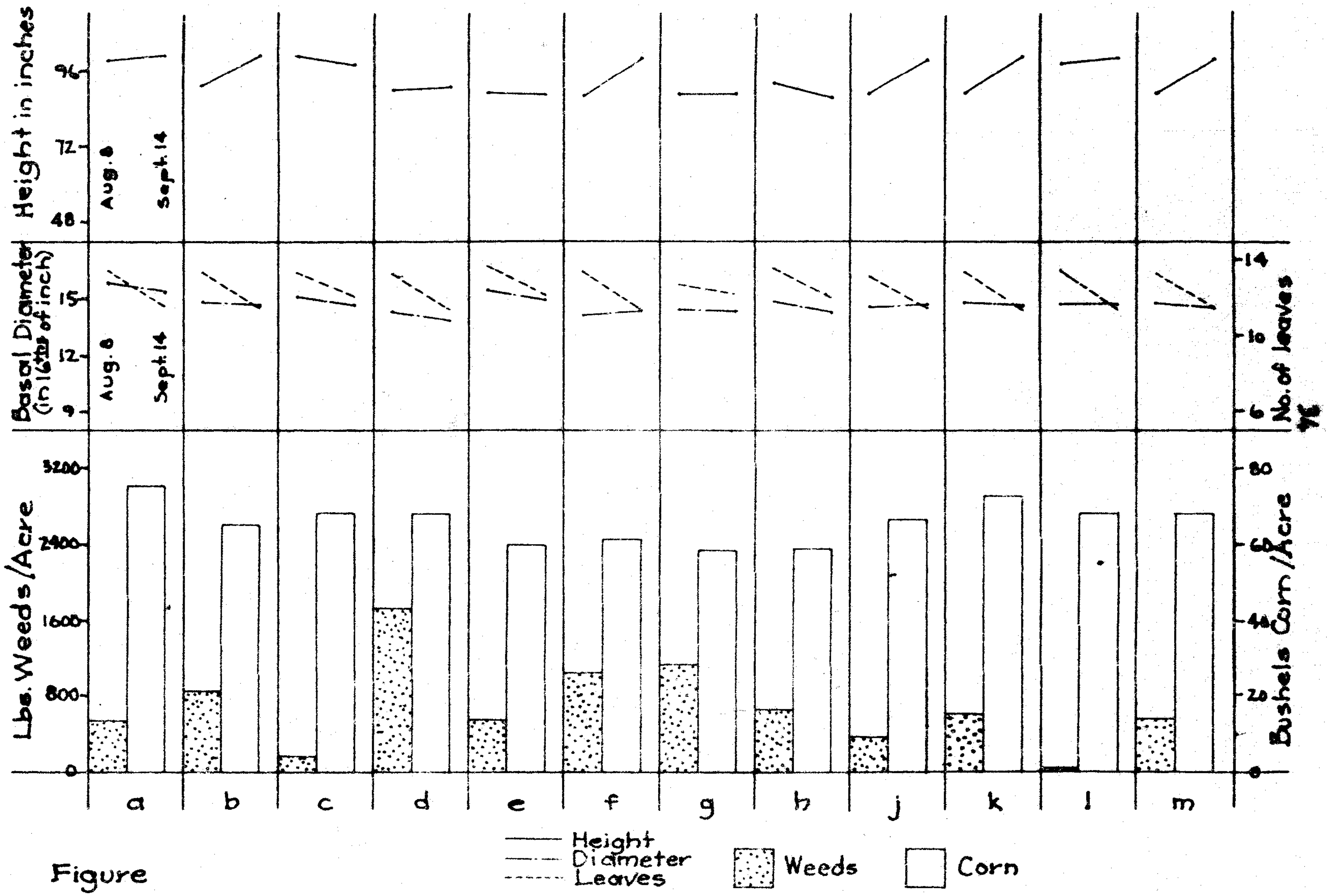
the growing season temperatures to be below normal (Table 2). In Figure 8 the rate of growth of the corn plants under the various treatments may be compared by comparing the angles of the lines connecting the two height measurements on August 8 and September 14, respectively. The fact that the heights are, with one exception, increasing while the diameters are decreasing would seem to indicate that the plants were being measured at one point during the period of maximum growth and at another following this period. At the latter date the plants had lost considerably in diameter probably due to differentiation and decreased succulence.

The average yield of corn ranged from a low of 58.9 bushels per acre in the g treatment plots to a high of 75.3 bushels per acre in the a treatment plots. All of the yield averages are presented in Table 3 and as vertical bars in Figure 8. Along with these crop yield data the average weed yields are presented as stippled bars in the figure. Weed yields were measured as pounds per acre and are directly comparable with the crop yield figures (one bushel equals 70 pounds of ear corn at 14.5 per cent moisture content).

The results of the statistical analysis of the crop yield data are given in Table 4. The least significant difference between the two treatments was 10.7 bushels per acre, and the difference between treatments was significant at the five per cent level.

Many of the treatments were similar whereas others differed widely. When arranged in order of decreasing yield they seemed to fall into three general classes of productive efficiency with less difference between the

Figure 8. 1950 growth measurements. Bars represent yields of corn and weeds; lines represent stem diameters, heights and leaf numbers.



Height in inches
96
72
48
Aug. 8
Sept. 14
Basal Diameter (in 16ths of inch)
15
12
9
No. of leaves
14
10
6
Lbs. Weeds/Acre
3200
2400
1600
800
0
Bushels Corn/Acre
80
60
40
20
0
a
b
c
d
e
f
g
h
j
k
l
m
Height
Diameter
Leaves
Weeds
Corn

Figure

Table 3. Crop yields, 1950. For description of treatments see list of abbreviations, p. iv.

	Treat-ment	Corn yield in bushels per acre: Treatment yield	Corn yield in bushels per acre: Class average	Max. height (ft.)	Max. av. diameter (16ths in.)	Max. leaf no.
Class 1	k	73.1				
	a	71.7	72.5	8.14	14.8	11.7
Class 2	c	68.7				
	d	68.0				
	l	67.7				
	j	66.6				
	b	65.4	67.3	8.03	14.4	11.4
Class 3	f	61.8				
	e	60.2				
	h	59.4				
	g	58.9	60.1	7.96	14.4	12.0

Table 4. Analysis of variance of 1950 crop yields

Source	d.f.	M. S.	F
Replicates	7	350.40	3.09**
Treatments	10	240.31	2.12*
Error	78	113.43	
Total	95		

**Significant @ 1% level.
*Significant @ 5% level.

L. S. D. @ $P_{.05}$ = 10.7

C. V. = 15.5%

members of each class than between the two adjacent treatments of the separate classes (Table 3). Treatments k and a yielded 73.1 and 71.7 bushels per acre respectively. These were the only ones yielding more than 70 bushels per acre. The yields of the next five (c, d, l, j and b) ranged from 65.4 bushels per acre (b) to 68.7 bushels per acre (c) and constitute an intermediate class. The remaining four treatments (f, e, h, and g) yielded from 61.8 bushels per acre (f) to 58.9 bushels per acre (g). The mean yield of the high yielding class was 72.5 bushels per acre, the middle class 67.3 bushels per acre and the low class 60.1 bushels per acre.

The high yielding class had received three normal cultivations (a) or three normal cultivations with a spray of sodiumethylsulfate, five pounds per acre (k). The treatments which fell in the middle class (b, c, d, j and l) included three of the five which had been treated with a two pound per acre pre-emergence 2,4-D spray and cultivated three, two and one times respectively (b, c, d). The other two treatments in the middle class had received a post-emergence treatment of two pounds per acre with three cultivations (j) and three cultivations with hand-weeding (l).

The low yielding class (e, f, g and h) included most of the post-emergence spray (one-half pound per acre of 2,4-D) treatments, one of which (e) had also received two pounds per acre pre-emergence spray and no further treatment, one (f) the first two cultivation treatments, one (g) the first and third cultivation treatments, and one (h) the second and third cultivation treatments.

1951 experiments. Evaluation of the experimental results of 1950 indicated the need for information on other aspects of corn-weed interactions. A study of these aspects based on results obtained during the growing and harvesting season in 1950 led to an expansion of experimental treatments to be investigated in 1951. Field D-2 (Figure 2) was identical to the pioneering experiment of 1950. Another experimental field, F-2 (Figure 3) at the Agricultural Engineering Farm was designed to compare, primarily, the substitution of spray for cultivation as a weed control method. The extent of its effectiveness was compared by applying the spray at each of two rates (one pound per acre and two pounds per acre) to plots that had no cultivation and to others that had one, two and three cultivations, respectively. Check plots were given three normal cultivations and no spray treatment. Each plot was separated into two subdivisions to compare overall application (o) with the ten and one-half inch strip applications (s). The former treatment gave complete coverage whereas the latter was applied at a low level directly over the rows to fall on strips adjacent to the corn plants, but not on the spaces between the rows.

The 1951 repeat of the 1950 experiment at the Agricultural Engineering Farm gave different results of corn-weed competition because of unusual variation in the weather. Heavy rains at about the time that the preparations of the field for planting should have been going on in 1951, delayed these operations. This altered the rate of development of crop and weeds and resulted in different weed control responses. The corn and weed seedlings were at different stages of development both at the time of cultivation and at the time of the spray applications.

The rainfall pattern (Table 5) was characterized by heavy accumulations throughout the year. Seven months of the year were above normal and four of the five which showed below normal rainfall were less than one-half inch below normal. The 3.79 inches excess in March and April plus the above normal rainfall in early May postponed planting into the first part of June. For this reason the soil moisture was abnormally high and the below normal total rainfall in May had no retarding effect on the early development of the corn. The saturated condition of the soil prevented the proper and timely preparation of the seedbed and the proper application of cultivation treatments. This explains the late maturity and high moisture of the corn and concomitant low yield.

Table 6 shows the monthly mean temperature as well as the normal monthly temperature and departures from the normal. The third column shows negative values except for the month of May. These below normal temperatures characterized this growing season and supplemented the late planting in contributing to the late maturing, low yielding, high moisture corn (Figure 9).

The least significant difference between treatments was 10.4 bushels per acre. Again as in 1950, the average yield figures of all treatments were arranged in order of decreasing magnitude and grouped into three classes with greater difference between the classes than between the members of each class (Table 7). The highest yielding treatment (e) at 65.4 bushels per acre exceeded the average of the middle ranking plots (b, k, c, l, i, f and a) at 57.2 bushels per acre which ranged between 52 and 60 bushels per acre. The lowest yielding class (treatments g, h, d and m) ranged between 28 and 50 bushels per acre with a mean of 41.4

Table 5. Precipitation observed at the Agronomy Farm, Ames, Iowa, 1951

Month	Rainfall		Departure	Accumulated departure from normal	
	Observed	Normal	from normal	Entire year	Growing season
January	0.38	0.87	-0.49	-0.49	
February	2.41	0.98	1.43	0.94	
March	3.05	1.43	1.62	2.56	
April	4.78	2.61	2.17	4.73	2.17
May	3.73	4.18	-0.45	4.28	1.72
June	7.21	4.34	2.87	7.15	4.59
July	4.49	3.42	1.07	8.22	5.66
August	5.47	3.70	1.77	9.99	7.43
September	3.14	4.28	-1.14	8.85	6.29
October	3.74	2.38	1.36	10.21	7.65
November	1.22	1.51	-0.29	9.92	
December	0.71	1.05	-0.34	9.58	
Totals	40.33	30.75	9.58	9.58	7.65

Table 6. Average temperature observed at the Agronomy Farm, Ames, Iowa, 1951

Month	Average temperature		Departure
	Observed °F.	Normal °F.	from normal °F
January	18.2	19.9	-1.7
February	23.7	22.8	0.9
March	26.4	35.9	-9.5
April	44.9	49.0	-4.1
May	62.2	60.6	1.6
June	65.3	69.6	-4.7
July	71.8	74.9	-3.1
August	70.6	72.5	-1.8
September*	59.8	64.4	-4.6
October	51.6	52.6	-1.0
November	31.0	37.6	-6.6
December	19.6	24.4	-4.8

*Killing frost occurred September 28.

Figure 9. Growth measurements, 1951. Bars represent yields of corn and weeds; lines represent stem diameters, heights and leaf numbers.

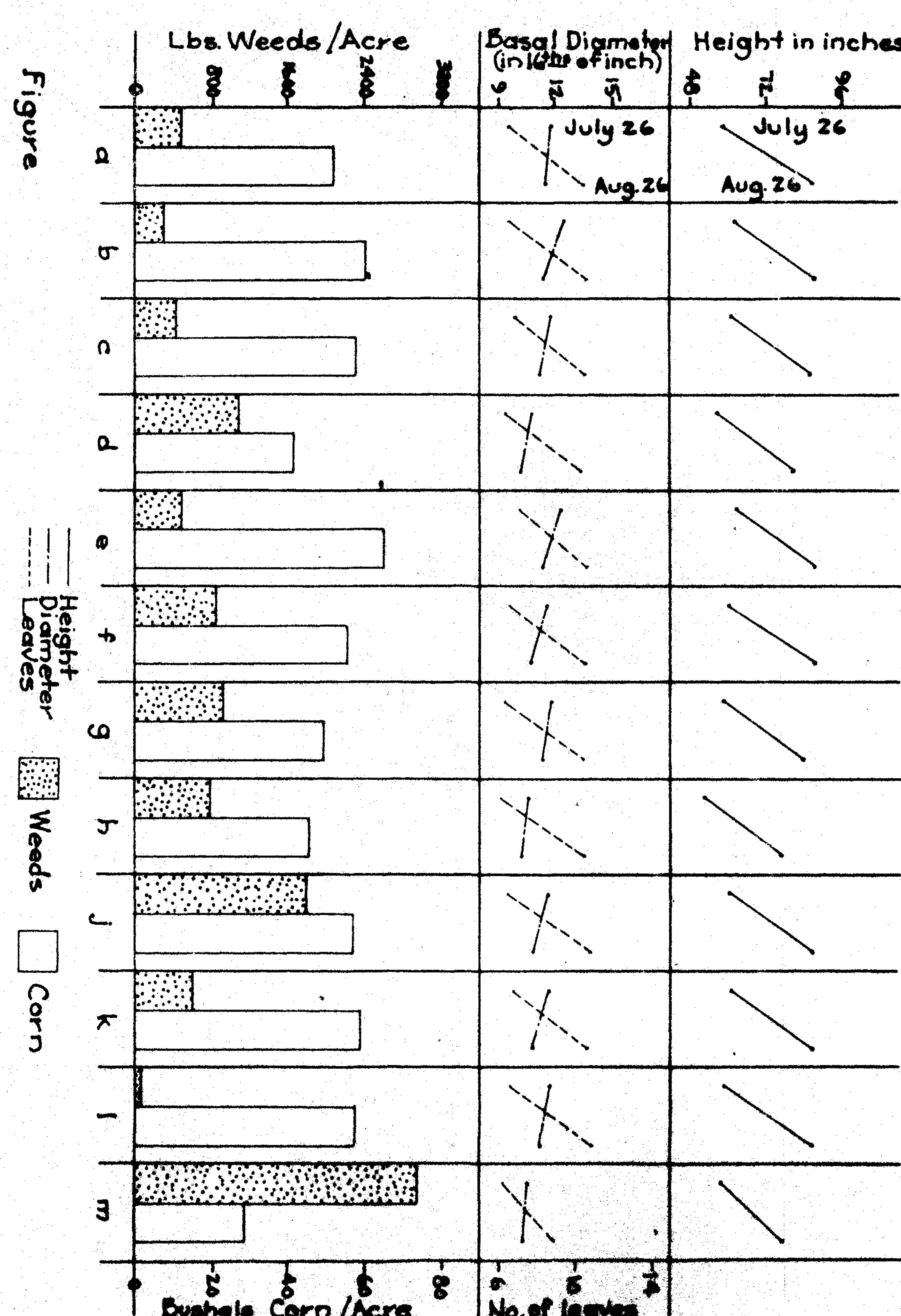


Figure
a b c d e f g h j k l m
Lbs. Weeds /Acre
0 800 1600 2400 3200
Bushels Corn /Acre
0 20 40 60 80
Basal Diameter (in 16ths of inch)
9 12 15
No. of leaves
6 8 14
Height in inches
48 72 96
July 26
Aug. 26
Height
Diameter
Leaves
Weeds
Corn

bushels per acre. In 1951, the highest yielding class (e) consisted of both pre-emergence and post-emergence spray and cultivation if necessary. No cultivation was applied. The middle class consisted of the two and three cultivation treatments with and without pre-emergence 2,4-D spraying (a, b, c) and post-emergence 2,4-D spray substitution for the third cultivation (f), three cultivations with post-emergence 2,4-D spray (j), with sodiumethylsulfate at four pounds per acre (k) and with hand-weeding (l). The lowest yielding class consisted of pre-emergence spray with only the third cultivation (d), post-emergence spray with second and third cultivations (h) and pre-emergence spray with no further treatment (m). Differences between treatments were highly significant (Table 8).

Dry weights of cut weeds from 42 inch x 80 inch randomly selected samples within each plot were determined. However, this was done during September and the results were very unfavorable. The foliage was dry and most of the leaves were gone. The results did not agree with observations made on the growth during the season nor correlate inversely with the corn yield results.

In general the results were very different from those obtained from the same experiment in 1950. Pre-emergence applications of 2,4-D amine, two pounds per acre acid equivalent applied directly after planting, gave better control of weeds and higher corn yields as compared to the weed control and yields obtained from areas where three normal cultivations were made. Substitution of the pre-emergence spray treatment for the first cultivation seemed to be more effective than in 1950. Substitution of spray for more than one mechanical cultivation did not reduce yields as

Table 7. Crop yields in field D, 1951. For description of treatments see list of abbreviations, p. iv.

	Treat-ment	Corn yield in bu/A Treatment yield	Class average	Maximum height (ft.)	Maximum av. diameter (16ths in.)
Class 1	e	65.39	65.39	7.3	11.3
Class 2	b	60.28			
	k	59.15			
	c	58.33			
	l	57.56			
	j	56.80			
	f	56.08			
	a	52.46	57.24	7.1	11.2
Class 3	g	49.24			
	h	46.32			
	d	41.89			
	m	28.18	41.41	6.7	10.9

Table 8. Analysis of variance of 1951 crop yields in field D

Source	d. f.	M. S.	F
Replicates	7	220.64	2.04
Treatments	11	810.21	7.48**
Error	77	108.29	
Total	95		

**Significant at 1% level.

L. S. D. at $P_{.05}$ = 10.4 bushels

C. V. = 19.8%

greatly as in 1950.

Substitution of post-emergence applications of 2,4-D, one-half pound per acre acid equivalent, for mechanical cultivations were not too successful. Yields were significantly reduced in all cases in which this spray treatment was substituted for cultivations and these reductions were significant when it was for the first or second cultivations. Substitution of post-emergence spray applications for the third cultivation gave very good weed control and did not significantly reduce the yields. Late post-emergence applications of 2,4-D and sodiumethylsulfate gave excellent control of broad-leaf weeds but did not affect yields (Figure 9), possibly because of the late date of application.

As a supplement to the foregoing experiment in 1951, field F-2 (Figure 3) was designed and carried out at the Agricultural Engineering Farm to evaluate strip *versus* overall spraying. It can be seen from the analysis of variance, Table 9, that the variations among replicates, treatments, and cultivations were all significant at the five per cent level.

In examining the data for mean differences in yields between plots sprayed in ten and one-half inch strips directly over the corn row (*s*) and plots sprayed for overall coverage (*o*) no significant difference was found. The strip spraying method had been observed as giving more efficient weed control (9) during the growing season. Similarly, although the difference between rates of one and two pounds acid equivalent of 2,4-D per acre gave no significant difference in yields and stands of corn, weed control was somewhat better at the higher rate, especially where more than one cultivation was eliminated.

Table 9. Analysis of variance of 1951 crop yields in field F-2

Source of variation		d. f.	M. S.
Replicates		5	551.13*
Treatments		8	2214.76*
Check vs treatments	1		1991.04*
1# vs 2#	1		203.01
Cultivations	3		5047.05*
Cultivations x 1# vs 2#	3		127.63
Error (a)		40	66.42
Among whole plots alike		6	178.76
Strip spray vs overall spray		1	115.28
Spray x treatment		7	39.10
Error (b)		40	39.23
Among sub-plots alike		12	14.92
Total		119	

*Significant at 5% level.

L. S. D. at 5% level

1.	Among individual treatment mean yields, i.e. a vs b etc.	6.7 bu/A
2.	Between strip and overall spray for single treatment i.e. ao vs as etc.	7.3 "
3.	Between two treatment means for a given spray, i.e. ao vs bo etc.	8.5 "
4.	Between cultivation means regardless of spray, i.e. one cultivation vs two cultivations	4.8 "
5.	Check means vs treatment means, i.e.	4.4 "
6.	Between spray rate means regardless of cultivation	N.S.

The same method as in field D-2 was employed for measuring the weed control by determining weed yields from 42 inch x 80 inch randomized samples in individual plots. The weed samples were collected too late in the season, resulting in a great reduction in plant weight due to loss of leaves and seeds with drying. A representative distribution of large, scattered weeds may take moisture and nutrients equivalent to a similar yield weight consisting of many, small, evenly scattered weeds. These samples were not large enough to be representative of all of these variations.

The highest yielding class (Table 10) consisted of two treatments (ko and ao) which yielded 66.7 and 62.4 bushels per acre respectively, with a mean yield of 64.6 bushels per acre. The middle yielding class consisted of 11 treatments (es, bs, eo, fo, go, js, as, jo, bo, ks, and fs) with a mean yield of 56.6 bushels per acre. The lowest yielding class consisted of seven treatments (gs, cs, co, ho, do, hs and ds) with a mean yield of 30.2 bushels per acre. See Table 7 for the individual yields of each of these treatments. Figure 10 shows the growth for a representative treatment chosen from each of the three yield classes and the yield bars for all treatments.

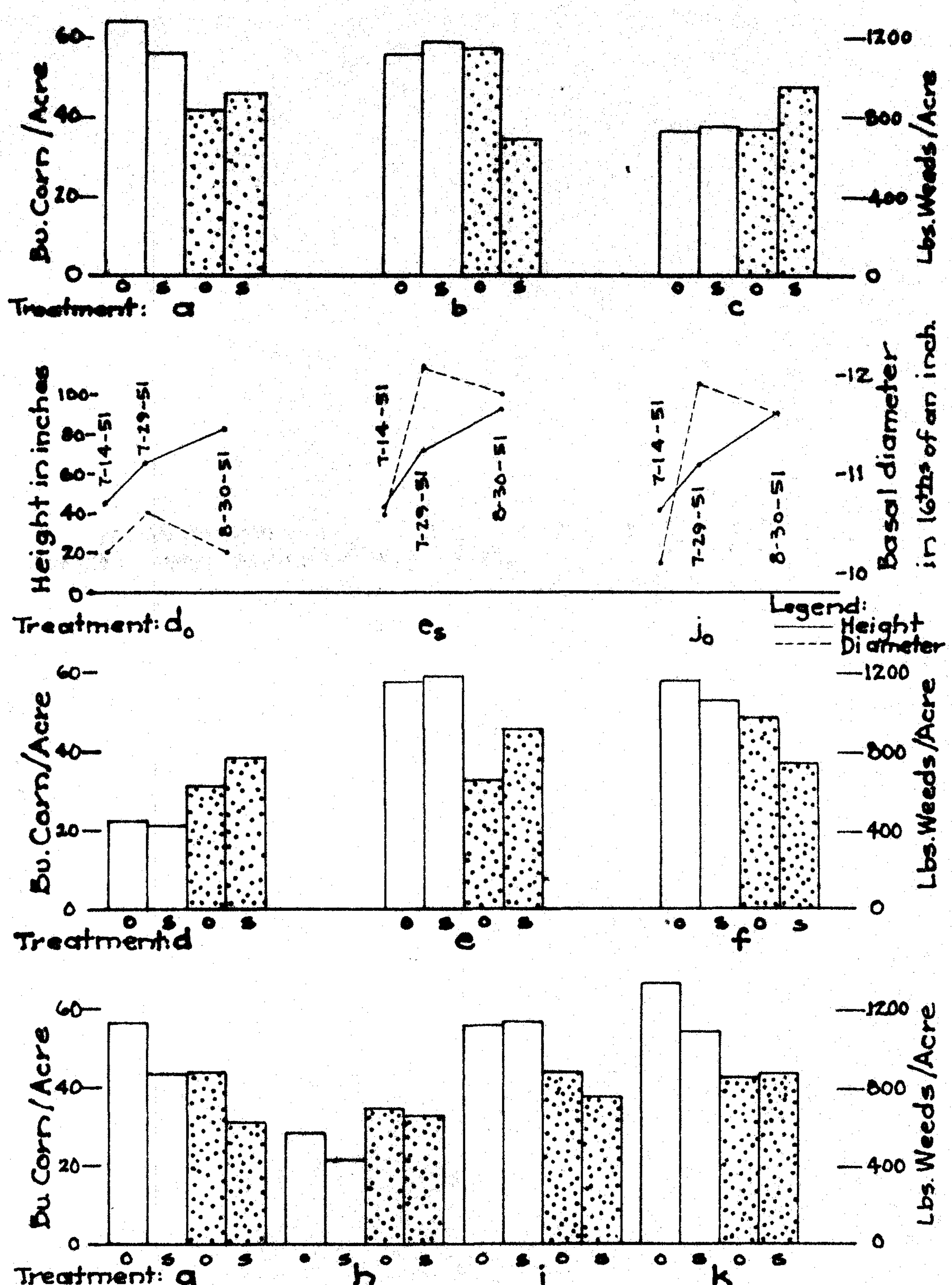
The two highest yielding treatments were both three normal cultivation treatments; the higher of the two without any spray treatment, the lower also received one pound per acre pre-emergence spray applied overall.

Treatments ao and ko both received three normal cultivations. Since k received no spray treatment ko and ks were identical treatments on adjoining plots. They ranked first and twelfth in production, respectively.

Table 10. Crop yield data in field F-2, 1951. For description of treatments see list of abbreviations, p. iv.

	Treat-ment	Corn yield in bu/A Treatment yield	Class average	Maximum height (ft.)	Maximum av. diameter (16ths in.)	Max. leaf no.
Class 1	ko	66.7		7.8	12.4	10.9
	ao	62.4	64.6	7.6	11.4	10.6
Class 2	es	59.4		7.8	12.2	11.1
	bs	59.0		7.9	11.4	10.3
	eo	58.0		7.4	11.3	10.4
	fo	58.0		7.8	11.2	10.6
	go	56.0		7.7	11.7	10.7
	js	56.3		7.6	11.6	10.6
	as	55.8		7.6	11.4	10.7
	jo	55.7		7.9	11.7	10.8
	bo	55.2		7.6	11.5	10.4
	ks	54.8		7.8	11.7	10.9
	fs	53.6	56.6	7.9	11.8	10.7
Class 3	gs	43.7		7.4	10.6	10.1
	cs	37.3		7.3	11.0	10.8
	co	36.8		7.0	11.1	10.7
	ho	28.2		6.8	10.7	8.8
	do	22.6		6.5	9.8	8.1
	hs	21.5		5.9	9.2	7.5
	ds	21.0		6.8	11.1	8.6

Figure 10. Growth measurements, field F, 1951. Bars represent yields of corn and weeds; lines represent stem diameters and heights.


Bu. Corn/Acre
Lbs. Weeds/Acre
Treatment: a
b
c
Height in inches
Basal diameter in 16ths of an inch.
7-14-51
7-29-51
8-30-51
Treatment: d_o
e_s
j_o
Legend:
Height
Diameter
Treatment: d
e
f
Treatment: g
h
j
k
Corn
Weeds

Figure

Treatment *a* received three normal cultivations and one pound per acre pre-emergence spray and the overall and strip divisions ranked second and ninth. Treatment *j* which received three normal cultivations, and was therefore identical with treatment *k* ranked eighth (*js*) and tenth (*jo*). It would seem that there was more variation between the like treatments (*ko* and *ks*) than there was between the several contrasting treatments making up these two classes, and for this reason it might be said that there was no significant difference between these particular treatments (*a*, *b*, *e*, *f*, *j* and *k*). Treatments *c*, *d* and *h*, both the *o* and *s* divisions, are grouped together in the lower third of the table and so would seem to constitute a low yielding class. These include all of the treatments that missed two or three cultivations with the possible exception of *go*, which received two pounds per acre pre-emergence overall spray application. Both strip and overall spraying showed improved weed control over the check plots and, although the yield differences were not significant, the yields from the sprayed plots were slightly higher than yields from the checks. When the pre-emergence herbicide applications were substituted for the first and second mechanical cultivations the yields were significantly reduced in all cases except where overall spraying was done at the heavy, two pound per acre, rate and even this treatment caused a slight reduction in yield. In addition to the lack of weed control and its competitive effect, initiated by the elimination of two cultivations with spray application, it was also observed that the excessive weed growth made it difficult to perform the last cultivation and reduced its efficiency as well as increasing its cost. Pre-emergence applications replacing all mechanical cultivations produced yields that were 25-30 bushels per acre less than the control, three normal cultivations. The weeds grew vigorously and the corn plants were light colored and stunted. For all practical purposes the weeds took over the plots where these pre-emergence spray applications were applied and not supplemented with subsequent mechanical cultivations. The corn plants seemed to be stooled and foxtail was present in abundance.

Competition Field Experiments

Ash Avenue Botany Research Farm studies

1951 experiments. The corn-weed competition experiments at Ash Avenue Botany Research Farm (Figure 4) were set up primarily to investigate the effect of weed presence and weed removal of varying degrees on corn yield. Secondarily, the comparative effectiveness of mechanical weed removal with and without various degrees of soil disturbance were observed. The treatment 0-W was hand-weeded but received no additional attention, 1-W received one, 2-W two and 3-W three cultivations in addition to hand-weeding. The UW series received comparable amounts of machine cultivation but no hand-weeding.

The yield of the hand-weeded plots was approximately 50 per cent greater than that of the unweeded plots (Table 11). Of the hand-weeded plots the 1-W was the most effective treatment in terms of yield. 0-W was the next most effective, 3-W next and 2-W least effective. Although the yield differences among the hand-weeded treatments are not statistically significant the order of the treatments seems to indicate a slight advantage of some cultivations over no cultivation as well as an advantage of three over only two cultivations (Table 12). The yields in the hand-weeded plots were so nearly identical that it is impossible to make a statement concerning the relative effectiveness of the amounts of soil disturbance as long as the weeds are controlled. However, the increase in competition brought about by lack of hand-weeding was evident in that the highest yielding plot of the intermediate group, treatment 2-UW, was clearly below the lowest yielding one of the high group, treatment 2-W (Table 11). The 3-UW treatment was slightly lower, possibly because of root injury caused by cross cultivation by hand plow. The treatments 1-UW and 0-UW were in the order that would be expected with the greater lack of weed control application. The negative effect of root injury, if significant here, is overshadowed by the positive effect of weed control.

The stalk yields were proportional to the grain yields. These, together with weed yields are given in Table 11. From these data it seems that although the 3-UW treatment did control the weeds better than the 2-UW, it did not produce as great a yield. This offers further evidence of root injury. The height of the corn plants seems to be affected by the competition only where the competition with weeds is most severe (Tables 11, 13).

The material presented in Figure 11 is compiled from the series of height measurements taken on treatments 3-W, 2-UW and 0-UW throughout the growing season. The three treatments are representative of the high, medium, and low yielding classes respectively. The very early effect of

Table 11. Corn and weed yields, Ash Avenue Botany Research Farm, 1951. For description of treatments see list of abbreviations, p. iv.

	Treat-ment	Grain yield (Bushels per acre)		Grain yield (lbs/A)	Stalk (lbs/A)	Total (lbs/A)	Weeds (lbs/A)
	1-W		76.5	4578	2185	6763	
Class	0-W		75.6	4525	2155	6679	
1	3-W		74.3	4447	2176	6623	
	2-W	74.49	71.6	4285	2017	6302	
Class	2-UW		56.4	3373	1932	5305	944
2	3-UW	55.2	54.0	3234	1716	4950	591
Class	1-UW		33.1	1983	1388	3372	1804
3	0-UW	23.3	13.4	802	976	1778	2286

Table 12. Analysis of variance of 1951 crop yields on Ash Avenue Botany Research Farm

Source	d. f.	M. S.	F
Replicates	7	1,845	1.27
Treatments	7	46,206	3.19**
Error	49	1,450	
Total	63		

**Significant at 1% level.

L. S. D. at $P_{.05}$ = 10.37 bushels per acre

C. V. = 20.7%

Table 13. Data and analyses of corn yields, plant heights and leaf counts, Ash Avenue Botany Research Farm, 1951. For description of treatments see list of abbreviations, p. iv.

Treatment		Corn yields (bu/A)	Plant heights (inches)	Leaf counts
3-W		74.3	97.0	9.95
2-W		71.6	93.9	9.78
1-W		76.5	95.8	10.09
0-W		75.6	95.4	9.94
3-UW		54.0	93.0	8.95
2-UW		56.4	92.4	8.62
1-UW		33.1	85.0	7.66
0-UW		13.4	70.4	7.44
Analyses of Variance				
Source	d. f.	M. S.	M. S.	M. S.
Replicates	7	1845.0	282.2**	1.359
Treatments	7	46206.0**	630.1**	9.025**
Error	49	1450.1	46.5	.821
Total	63			
L. S. D.		10.37 bu/A	6.85 in.	.902
C. V.		20.7%	7.6%	10.0%

**Significant at 1% level.

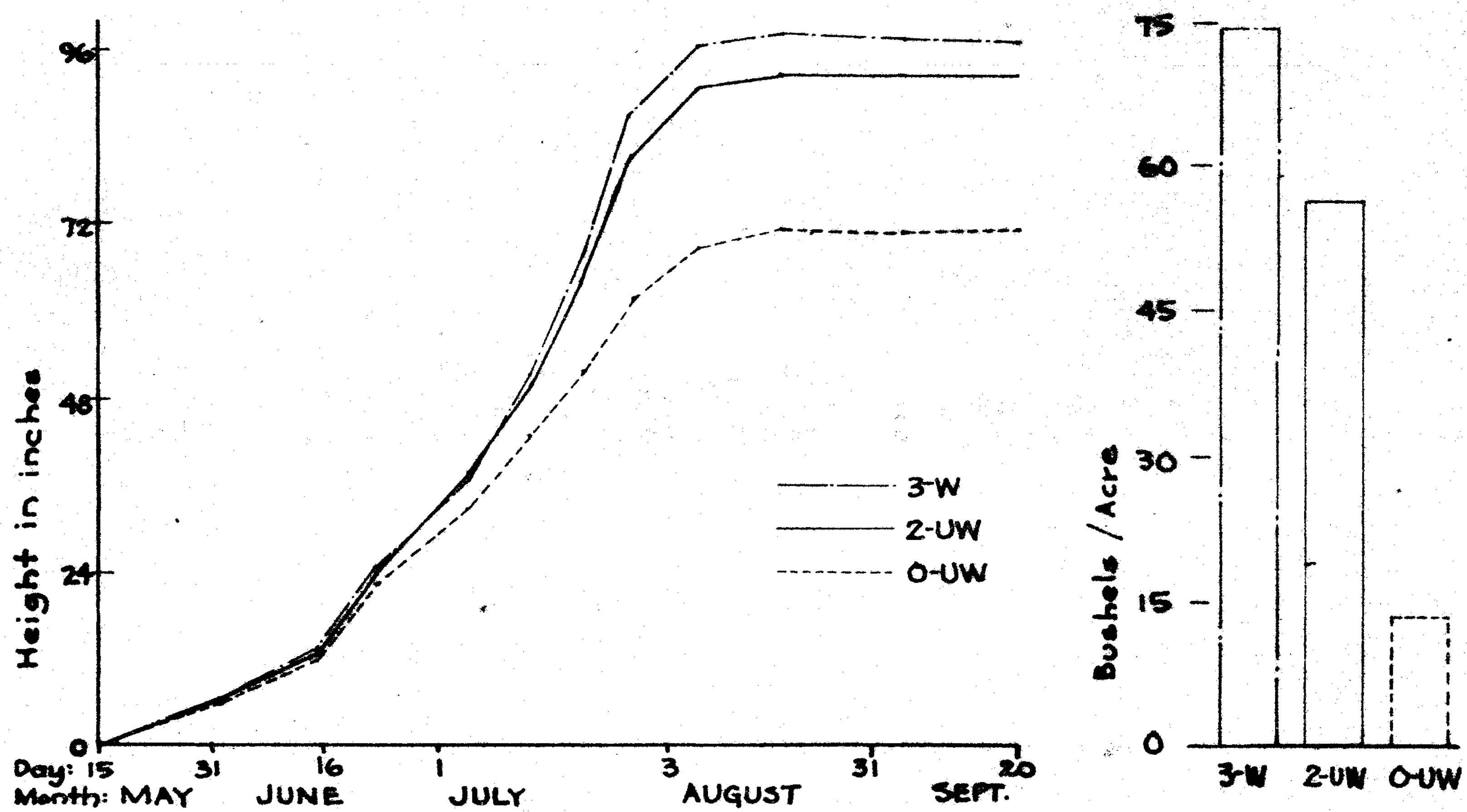
Correlation coefficients:

Yields: Heights = 0.960

Yields: Leaves = 0.970

Heights: Leaves = 0.998

Figure 11. Growth curves and yield bars, Ash Avenue Botany Research Farm, 1951. Three cultivations weeded (3-W), two cultivations unweeded (2-UW) and no cultivations unweeded (0-UW) treatments shown.



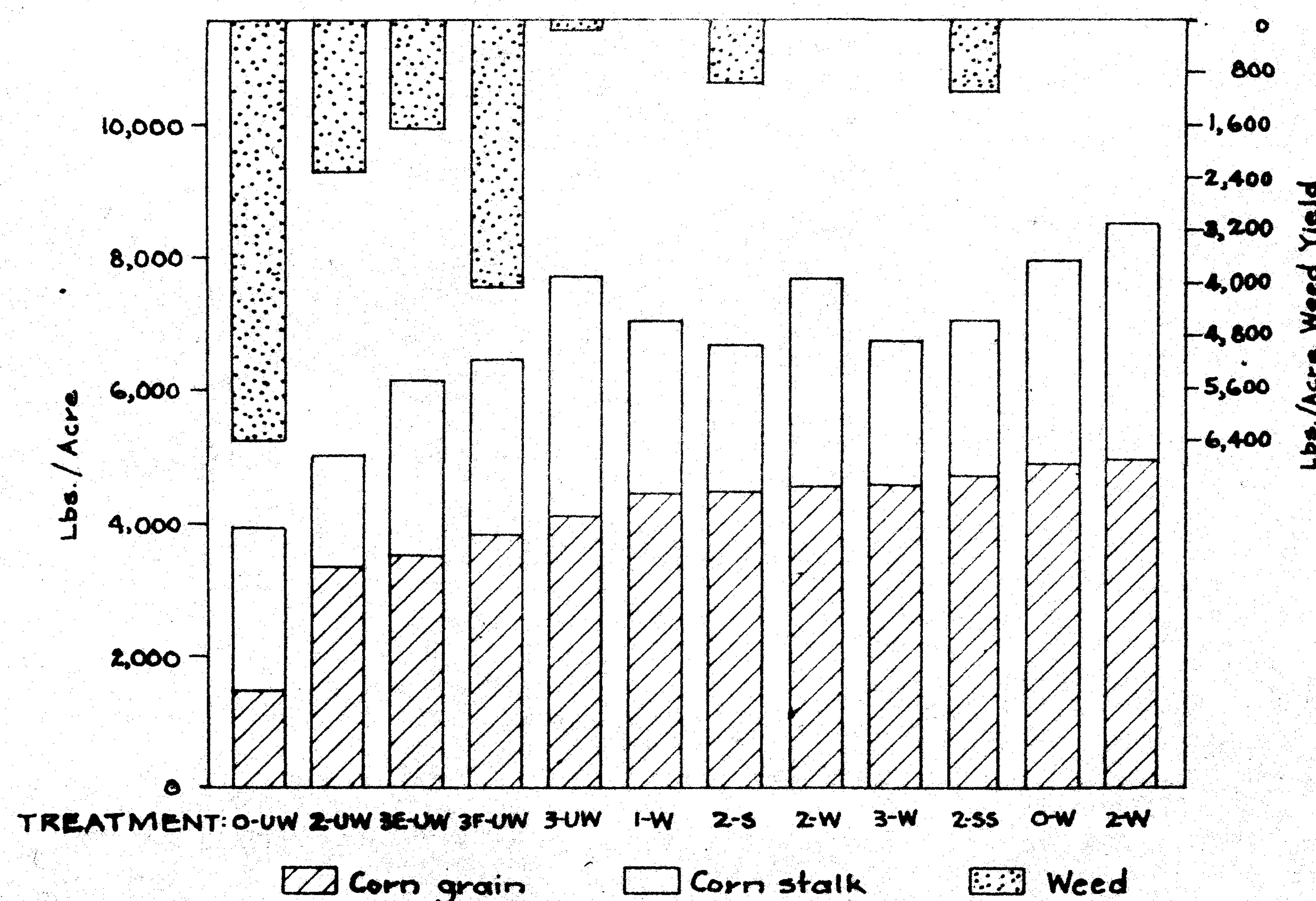
96
72
48
24
0
Height in inches
3-W
2-UW
0-UW
Day: 15
31
16
1
3
31
20
Month: MAY
JUNE
JULY
AUGUST
SEPT.
75
60
45
30
15
0
Bushels / Acre
3-W
2-UW
0-UW

Figure

competition on growth rate is seen in the separation of the growth measurements of the no cultivation and two cultivation plots beyond the one taken on June 23. This comparative slowing of the growth rate persisted and became even more pronounced as the period of severe competition lengthened. The complete leveling of the two curves took place at the same time, indicating the continuously increasing severity of the weed competition and perseverance of the corn plants. The yield figures, however, show the overall and most important effect.

1952 experiments. The Ash Avenue experiments were expanded in 1952 (Figure 5) to investigate the effectiveness of chemical weed control as compared to hand-weeding and standard cultivation control practices, and to repeat the investigation of 1951 which indicated that the additional injury of roots caused by the third cultivation being placed at right angles to the other two may have more than offset whatever weed control was attained thereby. The yield data presentation in the bar graph of Figure 12 includes the grain yield in pounds of dry matter per acre in the lower portion of each bar and the stalk yield in the upper portion. The weed yield represented on the same scale is drawn on the same graph as a bar extending down from the top margin of the graph. An analysis of variance of these data showed significance between treatments at the one per cent level (Table 14). To get some idea of the relationship between plant height and corn yield the average tassel heights at maturity were graphed in order of increasing corn yields (Figure 13). Although there is a general increase in height from left to right (from low to high yield) it does not correlate too closely with the order of yield increase.

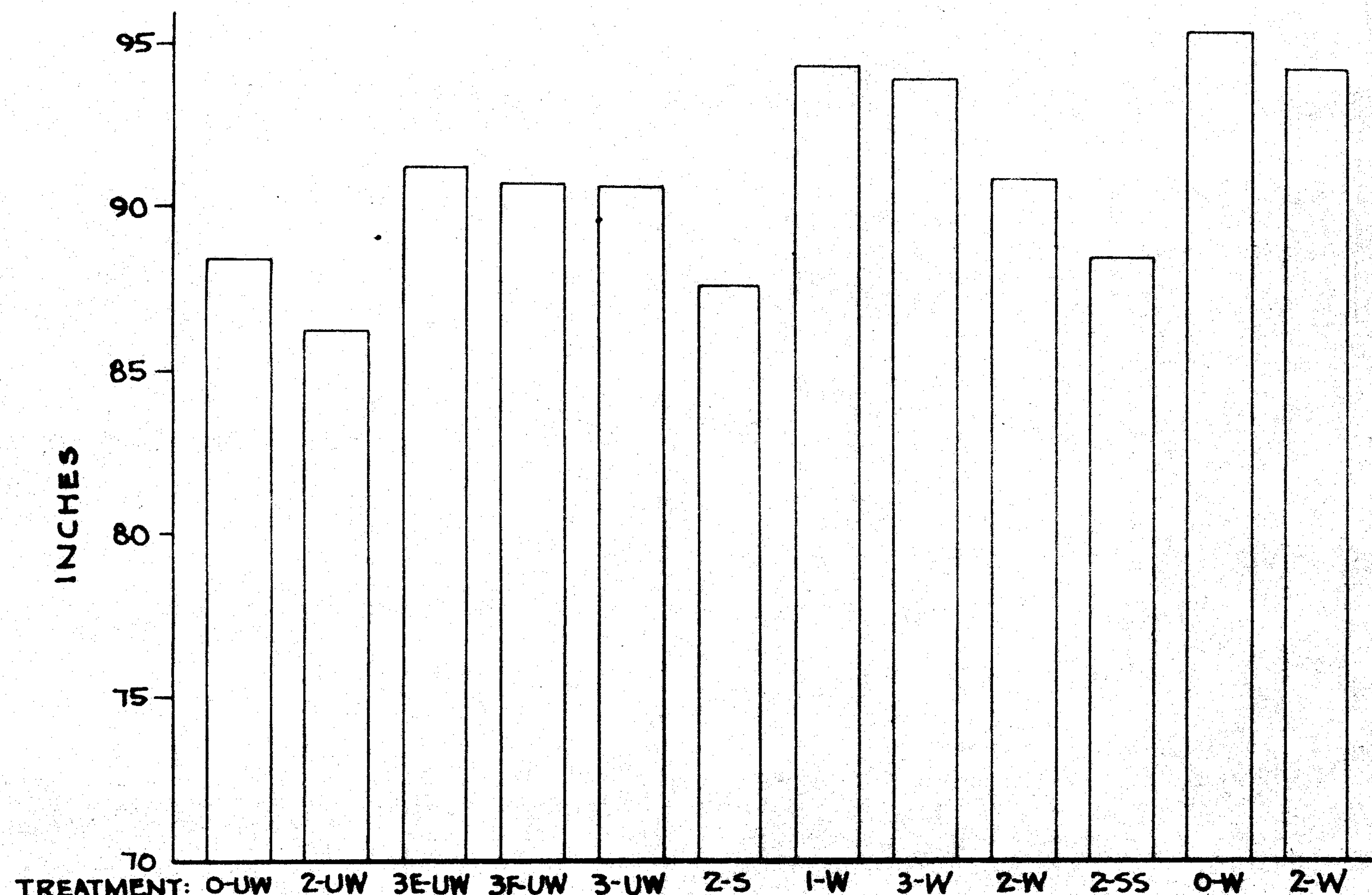
Figure 12. Stalk, grain and weed yields, Ash Avenue Botany Research Farm, 1952.



Lbs./Acre
0
2,000
4,000
6,000
8,000
10,000
Lbs./Acre Weed Yield
0
800
1,600
2,400
3,200
4,000
4,800
5,600
6,400
TREATMENT: 0-UW 2-UW 3E-UW 3F-UW 3-UW 1-W 2-S 2-W 3-W 2-SS 0-W 2-W
Corn grain
Corn stalk
Weed

Figure

Figure 13. Heights of the corn plants at Ash Avenue Botany Research Farm, 1952. Average tassel heights at maturity, arranged in order of increasing corn yield.



95
90
85
80
75
70
INCHES
TREATMENT: O-UW 2-UW 3E-UW 3F-UW 3-UW 2-S 1-W 3-W 2-W 2-SS 0-W 2-W

Figure

Table 14. Analysis of variance, 1952 crop yields, Ash Avenue Botany Research Farm. For yield data see appendix, Table 22.

Source	d. f.	M. S.
Replicates	3	315.79*
Treatments	11	966.84**
Error	33	82.57
Total	47	

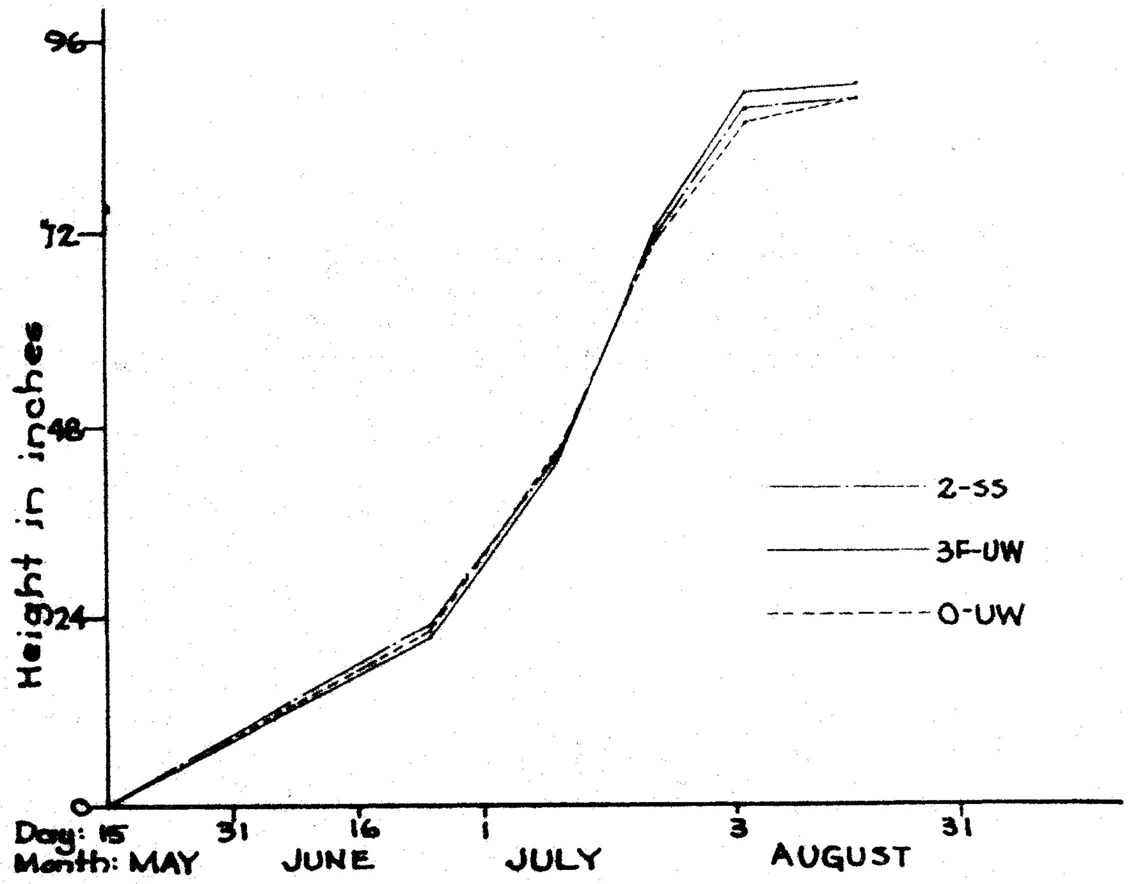
*Significant at 5% level.
**Significant at 1% level.

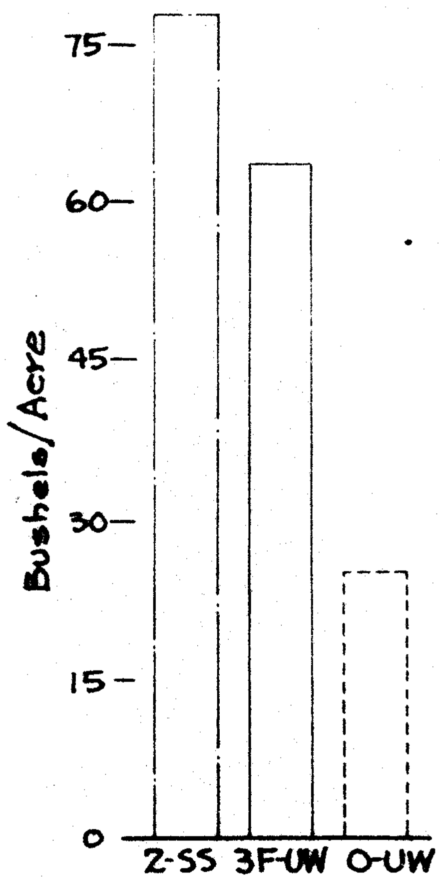
Correlation coefficient = 0.49

There is a positive correlation between height and yield of 0.49 (Table 14).

The various treatments may be grouped into three yield classes. A growth rate curve based on height growth for each of the three yield classes was constructed (Figure 14) for comparison with the 1951 growth rate curves (Figure 11). These curves show very little difference in height growth throughout the season, in spite of wide differences in yield. Height differences were much greater in 1951 (Figure 11). The high yielding class (81.3 to 73.7 bushels per acre) included seven treatments: two cultivations with hand-weeding, no cultivation with hand-weeding, two cultivations with pre-emergence spray and lay-by spray application, two cultivations with pre-emergence spray application and one cultivation with hand-weeding. The middle class (57.3 to 68.0 bushels per acre) included both the close and distant shovel treatments which were applied three

Figure 14. Growth measurements and yield bars for three representative treatments, Ash Avenue Botany Research Farm, 1952. Two cultivations with pre-emergence and lay-by spray treatments (2-SS), three cultivations with outside shovels (3F-UW) and no cultivations, unweeded (0-UW).


96
72
48
24
0
Height in inches
Day: 15
31
16
1
3
31
Month: MAY
JUNE
JULY
AUGUST
2-SS
3F-UW
O-UW


75
60
45
30
15
0
Bushels/Acre
2-SS
3F-UW
O-UW

Figure

times and the two and three cultivations with no additional treatment. The three cultivation treatment yielded 11 bushels per acre more than the two cultivation treatment; the close cultivation yielded six bushels less per acre than the distant cultivation. The low yielding class consisted of the no treatment plot and it was markedly lower than all other treatments.

The order of the components of the high yielding class presents an interesting picture including the individual variation between the double representation of two cultivations with hand-weeding, the slightly lower yield of no cultivation with hand-weeding, next lower two cultivations with two spray applications and next lower three cultivations with hand-weeding showing possible root injury. Two cultivations with one spray application and one cultivation with hand-weeding are the lowest members of this class.

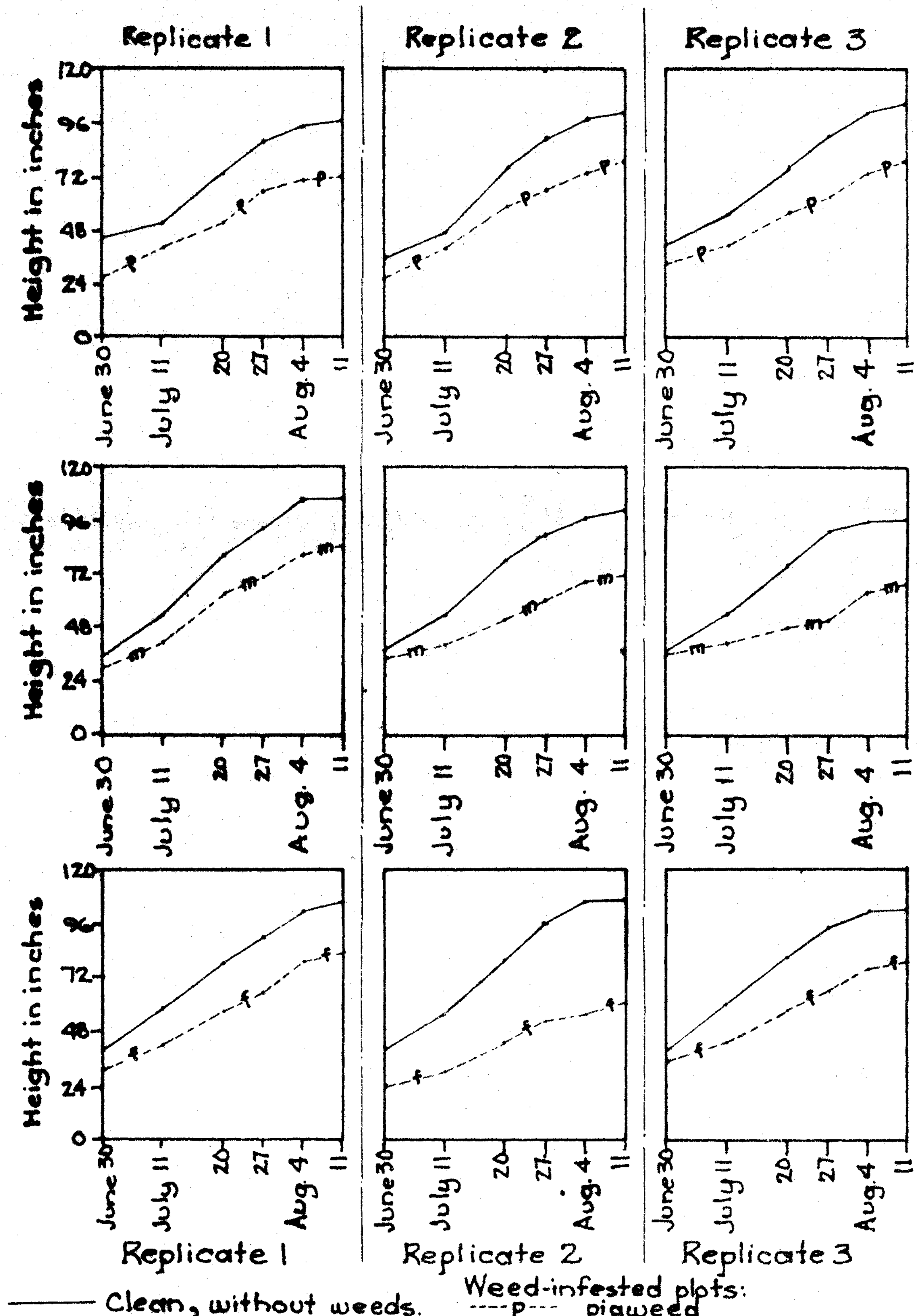
The middle class includes the close and distant cultivations which present some very interesting information. In spite of the better control of weeds in the close cultivation (Figure 12) the distant cultivation corn yield was slightly higher. This was probably due to the decreased amount of root injury and the greater efficiency of the corn plants as competitors with the weeds even though the weeds were present in greater quantity. The other two components of this class differ in yield by 11 bushels per acre with the three cultivation treatment yielding higher than the two cultivation treatment. The weed yields of these two are inversely proportional. The extremely low weed yield of three cultivations might be expected to net a greater increase in corn yield over the two cultivation treatment and the lack of proportionality (Figure 12) might very well be attributed to root injury, since three cultivations included a cross cultivation whereas in the two cultivation treatment both were in the same direction.

<u>Grass vs. broad-leaf weed competition studies</u>

<u>1953 experiments</u>. The weed species comparison experiments were designed to compare the competitive effectiveness of grass and broad-leaf weed species. In the nine plots of eight hills each, three were selected as containing an equal mixture of pigweed and foxtail, three were weeded to contain only foxtail and three to contain only pigweed. Nine contiguous plots were kept clean by hand-weeding as control plots. Growth rates were determined for the season by measurement of height, basal diameters and leaf count at intervals of a week to ten days until growth had ceased and are presented in Figure 15.

Yields of experimentally weed-infested plots were at least 66 per cent lower than the yields of adjoining control plots (Table 15). Summaries of the yields in the plots with individual weed species and with the two species mixed showed foxtail as the strongest competitor. The corn yield in this treatment produced 9.8 bushels per acre as compared to 111.9 bushels per acre in the adjacent control plots. The plots with a mixture of two week species produced 15.8 bushels of corn per acre and the adjacent controls produced 97.4 bushels per acre. Plots with pigweed alone as a competitor produced 31.8 bushels per acre as compared to 100.3 bushels per acre produced by the adjacent control plots. The stalk-ear ratio

Figure 15. Growth measurements, Dows, Iowa Farm, 1953. Average tassel heights of the mature corn plants under three weed-infestation treatments.



Replicate 1
Replicate 2
Replicate 3
Height in inches
120
96
72
48
24
0
June 30
July 11
20
27
Aug. 4
11
Clean, without weeds.
Weed-infested plots:
p pigweed
m mixed weeds
f foxtail

Figure

Table 15. Grain and weed yields, Dows, Iowa farm, 1953.

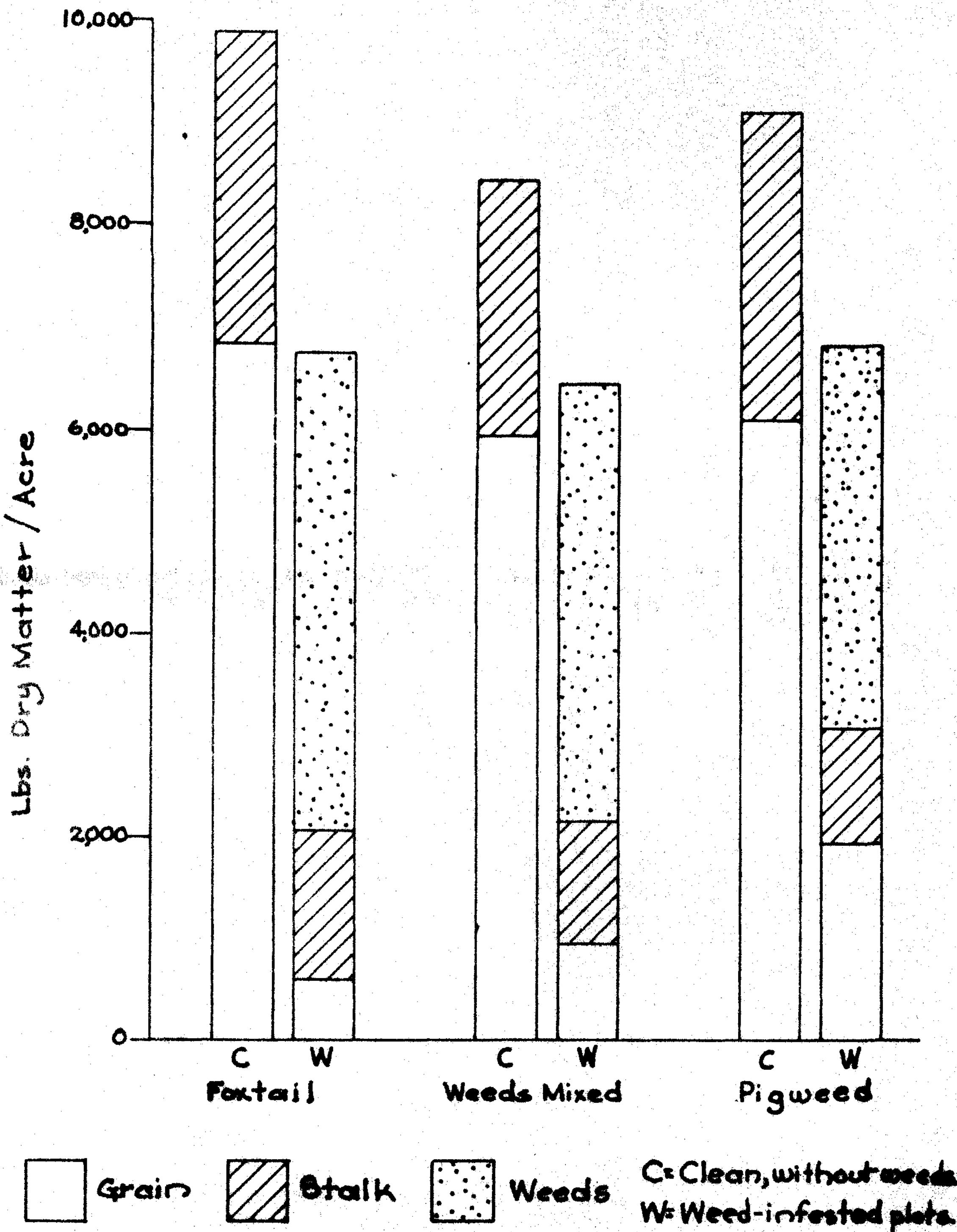
Treatments	Corn yield bu/A	Weed yield lbs/A
Hand-weeded corn	103.8	
Machine cultivated corn	77.7	
Pigweed infested corn	31.8	3954.1
Mixture infested corn	15.8	4275.9
Foxtail infested corn	9.8	4691.7

varied greatly among treatments. In all of the control plots combined it was 0.43; in the pigweed plots, 0.59; in the mixed weed plots, 1.42; in the foxtail plots 2.44. It was noted early in the season that the corn in the foxtail infested plots showed the yellowing of the terminal portions of the leaves characteristic of insufficient available nitrogen.

The average weed yields in pounds of dry matter per acre on all of the weed-infested plots was 4307.2. Foxtail plots averaged 4691.7 pounds per acre, mixed plots 4275.9 pounds per acre and pigweed plots averaged 3954.1 pounds per acre. These yields in pounds of dry matter per acre are compared to ear and stalk yields in Figure 16.

A compilation of the tassel heights at maturity showed that the foxtail infested corn averaged 6.0 feet, the corn infested with a mixture of the two weeds averaged 6.2 feet, the pigweed infested corn plants averaged 6.4 feet and control plants averaged 8.4 feet. Average basal

Figure 16. Average stalk, grain and weed yields in the three weed-infested treatments, Dows, Iowa, 1953.


10,000
8,000
6,000
4,000
2,000
0
Lbs. Dry Matter / Acre
C
W
Foxtail
C
W
Weeds Mixed
C
W
Pigweed
Grain
Stalk
Weeds
C= Clean, without weeds.
W= Weed-infested plots.

Figure

diameters of the mature corn plants listed in the same order were 12.6, 13.7, 12.6 and 17.2 sixteenths of an inch. The average leaf count at the last measurement was 9.6 in the foxtail infested plots, 9.5 in the mixture infested, 11.1 in the pigweed infested and 13.1 in the control plots.

From the above data it can be seen that foxtail had the strongest effect in decreasing the corn yield below the control yield, the mixture of the two weeds was intermediate and pigweed had the least effect on corn yield. The same order of effects was noted in the heights of the corn plants as well as on the basal diameters and numbers of leaves on the plants at the last date of measurement. The stalk-ear ratios were largest in the foxtail infested plots and progressively smaller through the mixture infested and pigweed infested plots to the lowest figure found in the control plots, indicating a decrease in the efficiency of the corn plants as crop producers along with their decrease in total dry matter production figures.

Yield measurements were taken from the machine cultivated corn field adjoining each of the plots listed here. This was done by picking corn from eight hills in these machine cultivated areas. They were found in each case to yield less than the contiguous hand-weeded plot but more than any of the adjacent weed competition plots.

The growth curves of the various treatments and controls are presented in Figure 15. The effect of weed competition on the corn can be seen by comparing the control plot growth rate with the weed-infested plot growth rate for each of the weed-corn treatments. The three replicates are presented separately. In a general way, the amount of area between the two curves is indicative of the degree of competition which this weed afforded the corn.

Competition Factor Experiments

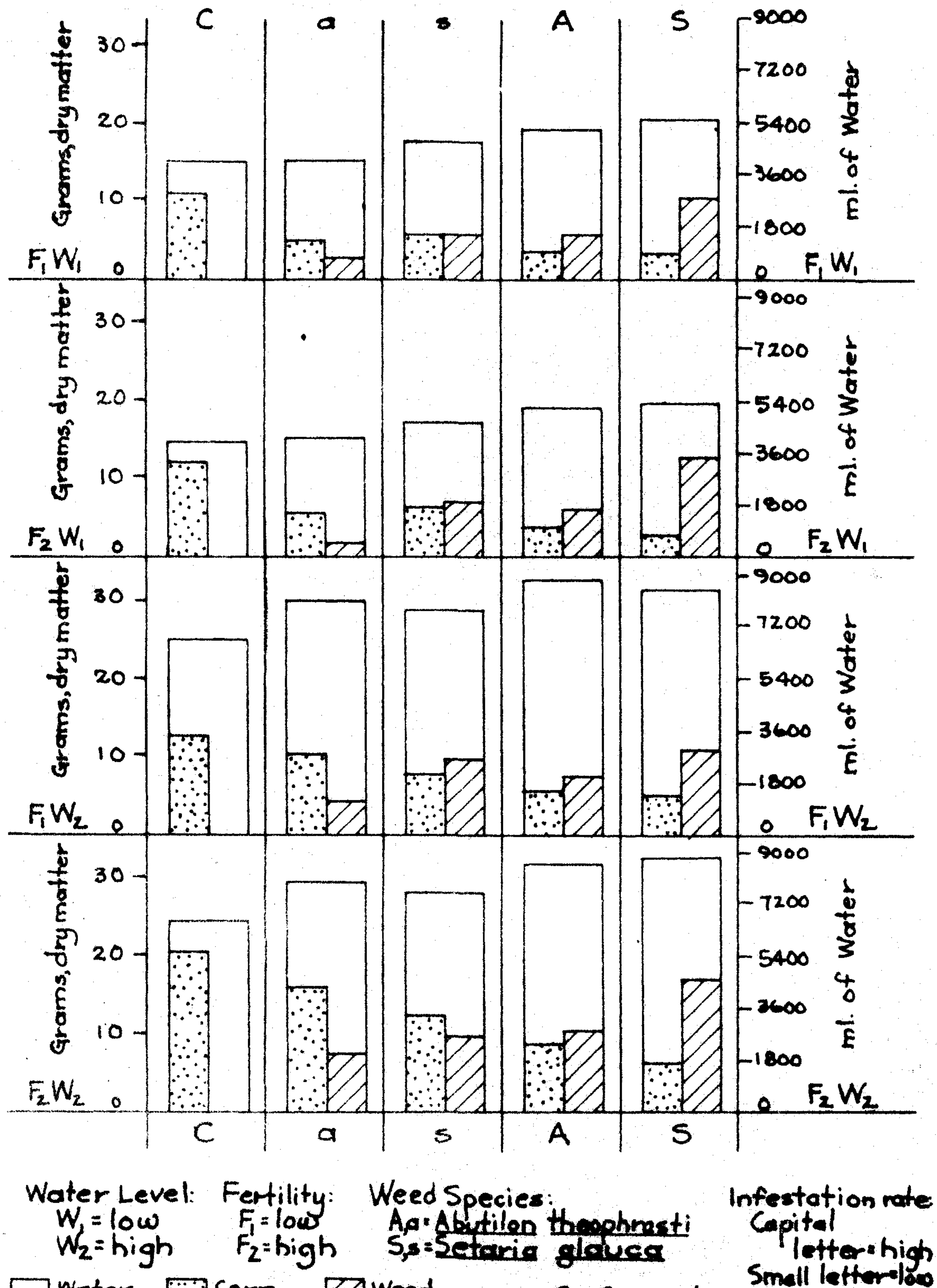
Greenhouse experiments

The greenhouse experiments were carried out during the winter of 1953-4 to study the behavior of the corn plant in competition with *Abutilon theophrasti*, velvet-leaf and *Setaria glauca*, foxtail. A corn plant was grown alone as a control in four different environments consisting of a high and low fertility soil and a high and low moisture content soil in all possible combinations. The experimental treatments of the four additional corn plants at each of these moisture-fertility levels, consisted of a high and low infestation rate of the velvet-leaf, and a high and low infestation rate of the foxtail.

The amount of moisture required to maintain each of these experimental treatments at a specified level is represented by the entire area of the bar in Figure 17. The area included in the stippled bar on the left of each small graph represents the dry weight yield of the corn plant and the cross-hatched bar on the right the dry weight yield of weeds. These are averages of the five replicates.

At the low water level the addition of fertilizer resulted in only a slight increase in yield, whereas at the high moisture level the fertilizer addition produced an appreciable increase in yield. The same trend is seen

Figure 17. Water used and yields of weeds and corn in the greenhouse experiments, 1953-4.


C
a
s
A
S
Grams, dry matter
ml. of Water
30
20
10
0
9000
7200
5400
3600
1800
0
F1 W1
F2 W1
F1 W2
F2 W2
Water Level:
W1 = low
W2 = high
Fertility:
F1 = low
F2 = high
Weed Species:
A,a = Abutilon theophrasti
S,s = Setaria glauca
Infestation rate:
Capital letter = high
Small letter = low
Water
Corn
Weed
C = Corn alone

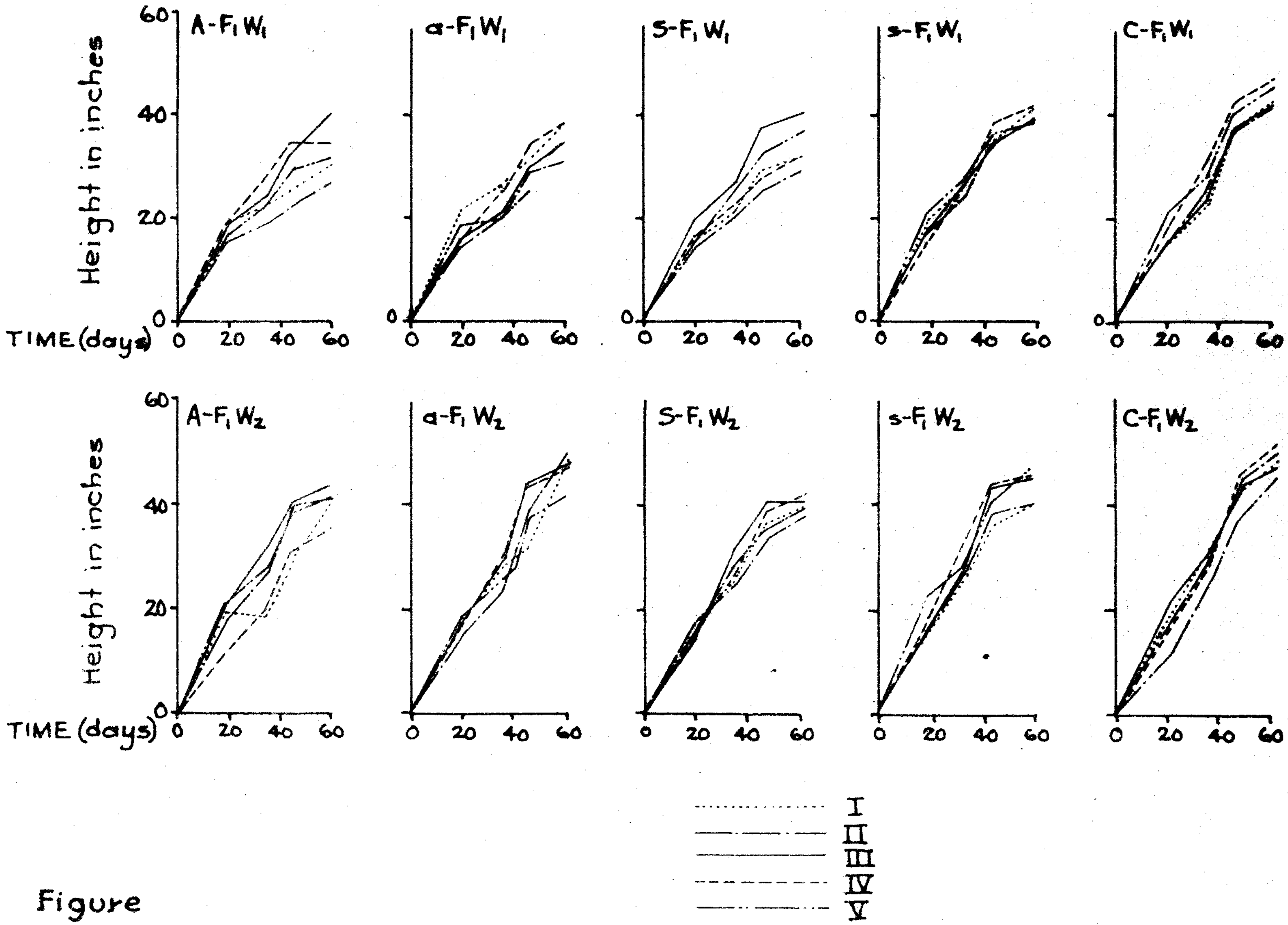
Figure

in each of the two competition treatments; the yield did not increase with increase in fertility if the moisture level was low whereas it showed marked increase, either in corn, in weeds or both, if the moisture level was high. In light weed infestation treatments the corn showed a greater response to increase in water supply than it did in the heavy weed infestation treatments. The increased quantity of weeds evidently reduced the supply of water sufficiently to cause this lack of response. Table 25 in the appendix shows the analysis of variance of both corn and weed yields and differences between treatments are significant at the 1 per cent level.

By reference to Figure 17 it is possible to compare the effectiveness of the two species of weeds as competitors with corn. By comparing one weed species with the other, either at a high or low infestation rate, and at any combination of water and fertility levels, it would appear that the foxtail caused a greater depression of the corn yield than did the velvet-leaf. The yield of weeds varied in the same direction; the foxtail always showed a higher yield than the velvet-leaf for any given infestation rate, fertility and moisture level.

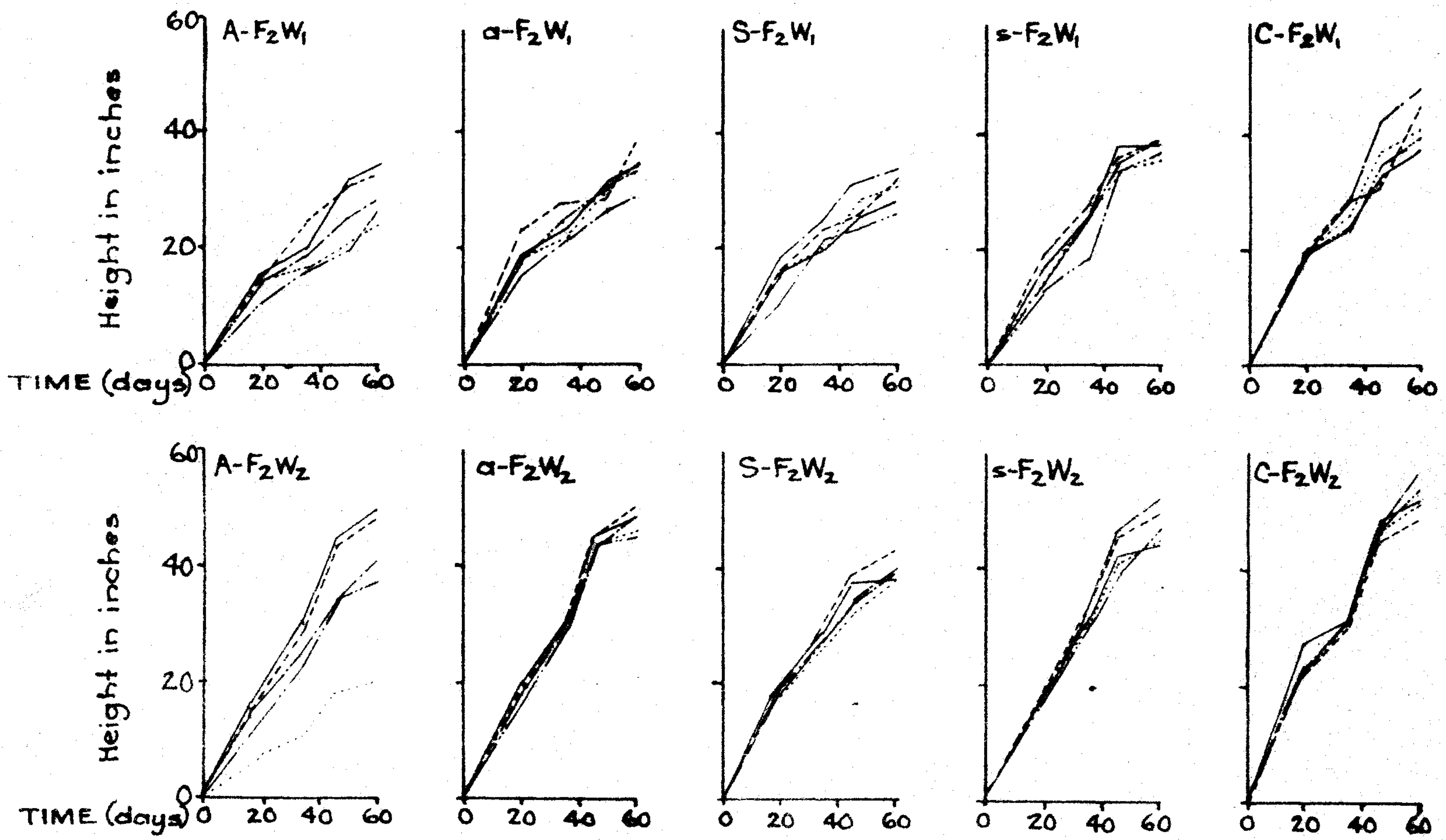
The growth curves (Figure 18) were constructed from the height measurements made at intervals of approximately two weeks and are presented here for each replicate and not for averages of the treatments. Several interesting comparisons may be made. By comparing the growth curve for each of the four combinations of moisture and fertility we see that in general the corn at the high water level (W_2) grew faster than that at the low water level (W_1). This was true at both fertility levels (F_1 and

Figure 18. Periodic plant height measurements of corn plants in the greenhouse experiments, 1953-4.



A-F_1W_1
a-F_1W_1
S-F_1W_1
s-F_1W_1
C-F_1W_1
A-F_1W_2
a-F_1W_2
S-F_1W_2
s-F_1W_2
C-F_1W_2
Height in inches
TIME (days)
0
20
40
60
I
II
III
IV
V

Figure



Fertility:
F_1 = low
F_2 = high

Water level:
W_1 = low
W_2 = high

Weed Species:
A, a = *Abutilon theophrasti*
S, s = *Setaria viridis*

Infestation rate:
Capital letter = high
Small letter = low

C = Corn alone.

Figure

F_2) for any of the plant combinations (heavy velvet-leaf with corn; light velvet-leaf with corn; heavy foxtail with corn; light foxtail with corn or corn without weeds). By making similar comparisons of the high fertility level (F_2) with the low fertility level (F_1) at both of the water levels (W_1 and W_2), we find that at the low water level (W_1) the low fertility treatment (F_1) resulted in greater corn growth than did the high fertility treatment (F_2). At the high moisture level (W_2) however, the high fertility treatment (F_2) resulted in greater corn growth than did the low fertility treatment (F_1).

Figure 19 shows the response of corn without weed infestation to the four combinations of two fertility and two moisture levels with the two low fertility treatments on the left and the two high fertility treatments on the right. At each of these levels the low moisture level treatment is on the left and the high one is on the right.

Figures 20 and 21 represent the low fertility and the high fertility series. They show the degrees of competition of both Setaria and Abutilon with corn at the four fertility-moisture combinations mentioned in discussing Figure 19. In each case the corn plant growing alone is on the left, followed by the low and high rates of Setaria infestation and then by the low and high rates of Abutilon infestation. The top photograph of Figure 20 is a series maintained at low fertility and low moisture levels whereas the bottom photograph is the low fertility, high moisture series. Figure 21 is the high fertility series, maintained at low moisture (above) and high moisture (below).

Figures 22 and 23 represent the low moisture and the high moisture

Figure 19. Greenhouse experiments, 1953-4, clean corn series. Low fertility-low moisture on the left, low fertility-high moisture second, high fertility-low moisture third and high fertility-high moisture on the right.


F

Figure 20. Greenhouse experiments, 1953-4, low fertility series. Clean corn, corn with *Setaria* at low (left) and high (right) infestation rates and corn with *Abutilon* at low (left) and high (right) infestation rates at low moisture above, high moisture below.

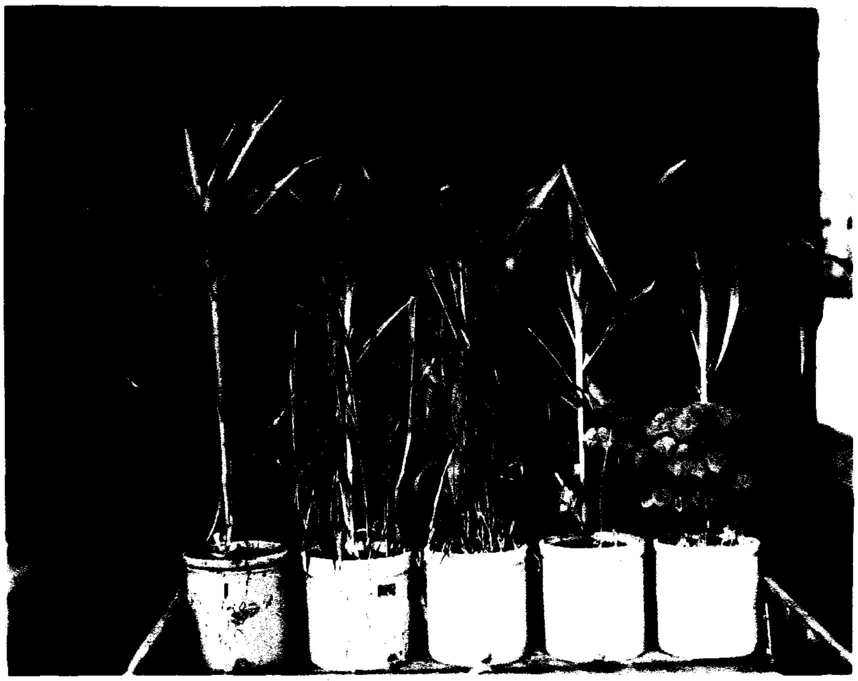


Figure 21. Greenhouse experiments, 1953-4, high fertility series. Clean corn, corn with *Setaria* at low (left) and high (right) infestation rates and corn with *Abutilon* at low (left) and high (right) infestation rates at low moisture above, high moisture below.

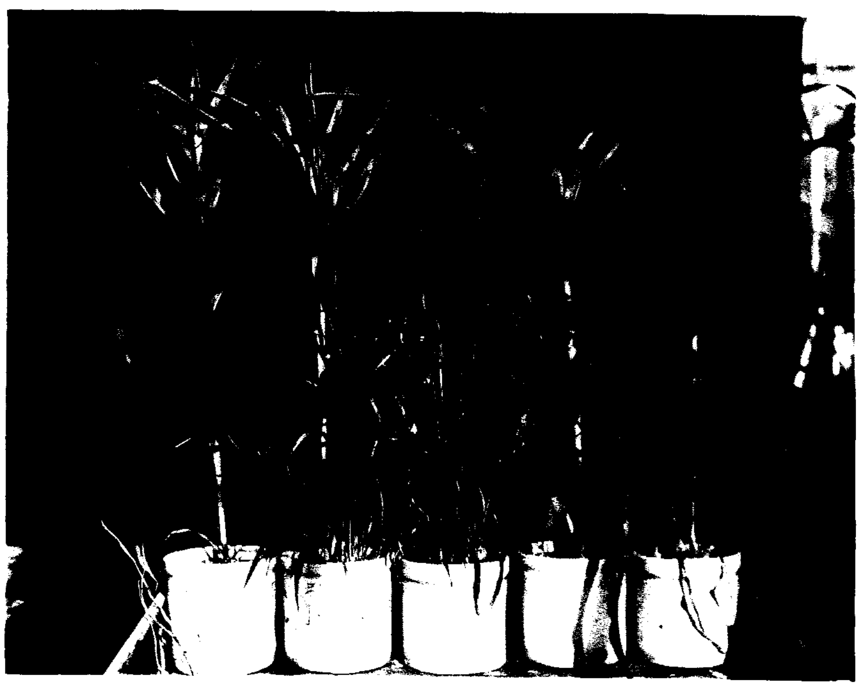
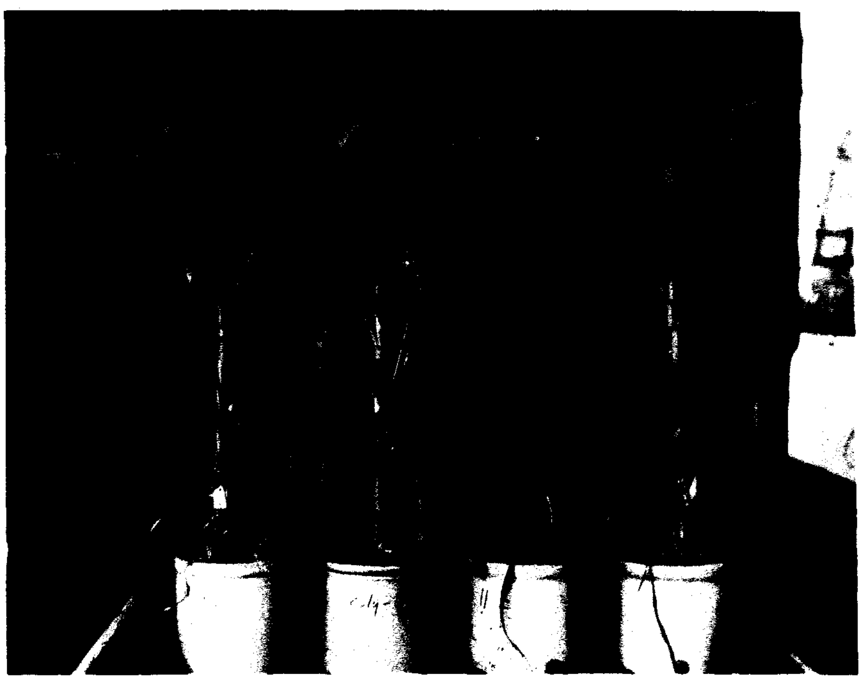


Figure 22. Greenhouse experiments, 1953-4, low moisture series. Corn with _Setaria_ (first and third) and _Abutilon_ (second and fourth) at the high infestation rate above and low infestation rate below. The two on the left received low fertility treatment and the two on the right the high fertility treatment.

Figure 23. Greenhouse experiments, 1953-4, high moisture series. Corn with _Setaria_ (first and third) and _Abutilon_ (second and fourth) at the high infestation rate above and low infestation rate below. The two on the left received low fertility treatment and the two on the right the high fertility treatment.



series. They compare the two low fertility treatments on the left with the two high fertility treatments on the right. The left one at each of these levels was infested with weeds at the low rate and the right one at the high infestation rate. The soil in Figure 22 was maintained at low moisture and that in Figure 23 at high moisture.

Figures 24 and 25 represent the foxtail series and the velvet-leaf series. They compare the two weeds, Setaria and Abutilon, at each of the fertility and water level combinations. Figure 24 shows the Setaria series at the low fertility level above; the left half at low water level and the right half at high water level. The first and third crocks are at low and the second and fourth are at high weed infestation rate. The same series of treatments at the high fertility are shown below. The crocks shown in Figure 25 were kept at fertility and moisture levels comparable to those of Figure 24. In Figure 25, however, the weed is Abutilon although the infestation rates are in the same order as those of Setaria in Fugure 24.

Figures 26 and 27 compare two rates of weed infestation. Figure 26 shows the low rate infestation, five weed plants per crock. The two low fertility treatments are on the left and the two high fertility treatments are on the right. Of each of these pairs, the low moisture level is on the left and the high moisture level is on the right. Figure 27 shows the high infestation rate, twenty weed plants per crock, responses for the same treatments in the same order.

Figure 24. Greenhouse experiments, 1953-4, foxtail series. Corn infested with *Setaria* at the low (first and third) and high (second and fourth) infestation rates. The upper photograph shows plants which received the low and the lower one the high fertility treatment. The left half of each received the low and the right half the high water level treatment.

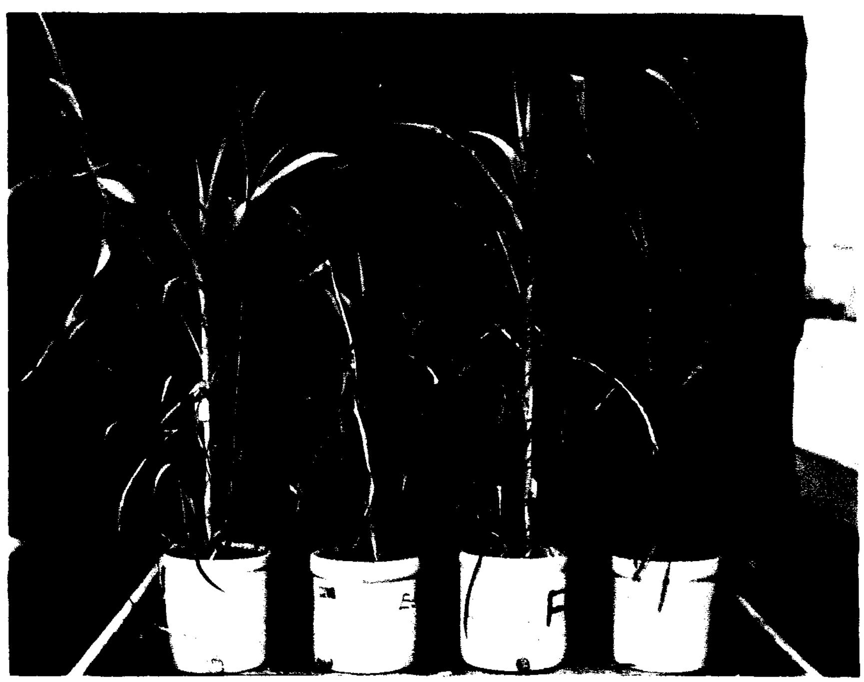


Figure 25. Greenhouse experiments, 1953-4, velvet-leaf series. Corn infested with *Abutilon* at the low (first and third) and high (second and fourth) infestation rates. The upper photograph shows plants which received the low and the lower one the high fertility treatment. The left half of each received the low and the right half the high water level treatment.

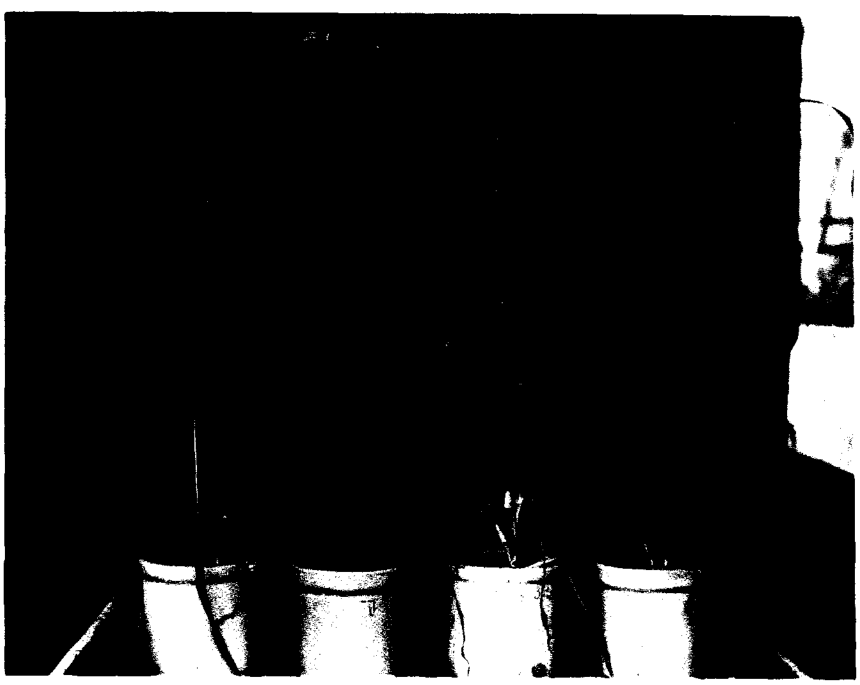
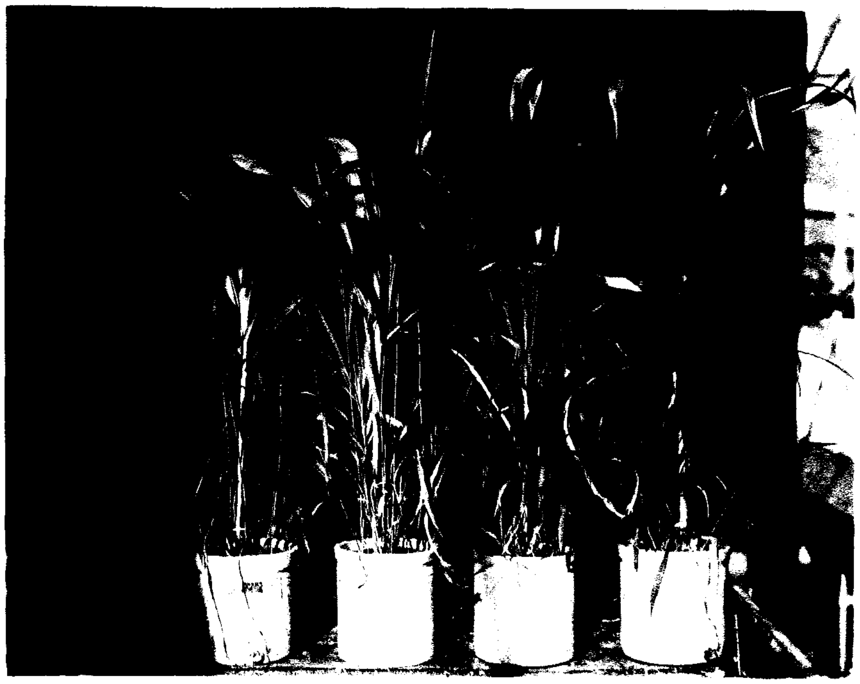


Figure 26. Greenhouse experiments, 1953-4, low infestation rate series. Corn infested at the low rate with *Setaria* (above) and *Abutilon* (below) and receiving soil fertility and moisture treatments as follows, from left to right: low fertility-low moisture, low fertility-high moisture, high fertility-low moisture, high fertility-high moisture.



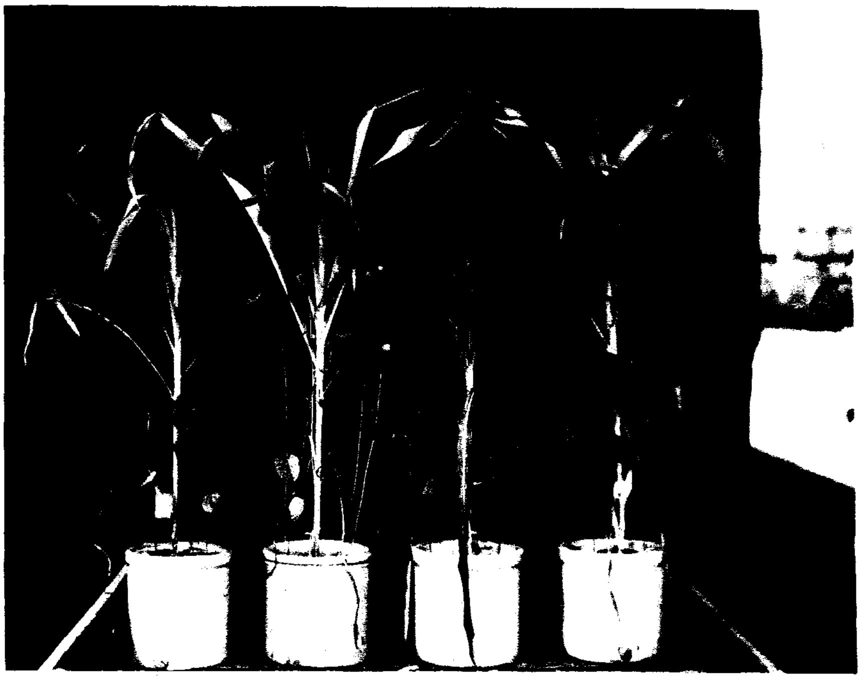


Figure 27. Greenhouse experiments, 1953-4, high infestation rate series. Corn infested at the high rate with Setaria (above) and Abutilon (below) and receiving soil fertility and moisture treatments as follows, from left to right: low fertility-low moisture, low fertility-high moisture, high fertility-low moisture, high fertility-high moisture.

DISCUSSION

Weeds compete with corn to the extent that their use of the factors of the common environment causes one or more factors to become limiting to the growth of the corn. The problem of determining to what extent and at what periods of the growing season the competition occurs and its effect on corn yield is an extremely complex one. Major variables contributing to the degree of complexity are: 1) the corn hybrid and the species of weed in competition; 2) the seasonal variability in the environment in terms of soil characteristics as influenced by soil type, rotations and fertilizer treatments and in terms of climatic conditions; 3) cultivation and other weed control measures employed.

In these experiments the corn hybrid and weed species when pertinent have been specified. The degree of seasonal variability during the four year period was considered to be slightly above average. Cultivation and other weed control practices were applied singly and in a large number of combinations to make possible an evaluation of their effectiveness in weed control, alone and supplemented by other practices. The variables in these experiments modified the principal factors in plant competition: water, nutrients, light and temperature. In this discussion an attempt will be made to clarify the effects of the major variables on the principal factors controlling growth of the plants and, through them, the response of corn and weeds in terms of growth and yield. The greenhouse experiments provide a source of information on the interactions of corn and weeds with growth factors which is of value in interpreting the results of field experiments.

Weed Control Machinery Experiments

1950-1951 Experiments

The weed control machinery experiments in 1950-1951, designed to evaluate a wide range of weed control methods in terms of corn yield, constitute a repetition of experiments in the same field under two different sets of weather conditions (Tables 1, 2, 5, 6). The results of identical weed control treatments for succeeding years were so widely different that it would seem reasonable to conclude that weather conditions may, and in this instance did, greatly influence the effects of the weed control treatments on the yield of corn. The only major factor besides weather that may have contributed to differences in the response of the corn for the two years was overall reduction in productivity of the plot field in 1951 because of corn following corn in the rotation. This may account for some of the reduction in yields of all of the treatments in 1951. In both years the hand-weeded treatment was applied too late to reduce the competition of the weeds.

The high yield of 75.6 bushels per acre obtained at Ash Avenue in 1951 by hand-weeding as compared to the low of 13.4 bushels per acre without any cultivation or hand-weeding indicates the response that may result from complete weed control. The Clements (3) term of incidence by which the reaction of the weed plant limits the development of the corn plant applies here. The water and nutrient factors probably were important in the early stages of plant development before the leaves had expanded sufficiently to limit the light available to the crop or weed. Later light probably became the limiting factor. At this later stage the cumulation (3) effect was evident in increasing the initial advantage of the weeds over the corn.

Several differences in yields are evident between the two experiments which may be attributed only to differences in the plant growth conditions, largely those of weather, during the two growing seasons (Tables 3, 7). In 1950 the average yield was 22 per cent higher than in 1951 and the differences in yield among the treatments were not so great. In 1950 the treatments with three normal cultivations and those with two normal cultivations with a pre-emergence spray substituted for one cultivation gave the higher yields. In 1951 spray treatments with or without cultivations gave the higher yields. A recapitulation of the conditions under which the two crops developed and of the response of the corn to these conditions is presented in partial explanation of the widely different effects of the weed control treatments.

Growth conditions for corn in 1950, although relatively unfavorable, did not reduce the yield below about 60 bushels per acre under the least effective weed control treatments. These conditions for growth of corn in 1950 were superior to those in 1951. The corn in 1950 was planted earlier and became better established during the month of June. Conditions for applying the cultivations required were more favorable. From the last of June to the close of the season the corn which received three normal cultivations or one adequate spray treatment with two cultivations developed with little competition pressure of the weeds. This corn made adequate growth and above average yields in spite of a relatively dry season.

In 1951 later planting in an extremely wet seed-bed contributed to inadequate establishment of the corn plants ahead of the weeds. Inability to apply adequate cultivation as required decreased the effectiveness of the cultivation treatments in controlling weeds. The poorly established corn growing under conditions of below normal temperature and above normal rainfall during the entire season was a foot shorter in height and one quarter inch less in stalk diameter than in 1950 (Tables 3, 7). Under these conditions adequate spray treatments were more effective in relation to growth and yield than were the treatments based on three cultivations.

There were several facts found to be true of these 1950 and 1951 studies, which were taken as rather sound premises for the design of further experiments. The pre-emergence application of two pounds per acre of 2,4-D acid equivalent as a substitute for the first of three normal cultivations in 1950 resulted in a yield greater than that produced after the three normal cultivations. The substitution of a single spray for more than one mechanical cultivation seemed to result in a significant reduction in yield. Post-emergence application of 2,4-D at the rate of one-half pound per acre acid equivalent was not too successful. Grassy weed species were not controlled by post-emergence applications of 2,4-D and therefore overall weed control was not as effective with this treatment alone as with at least some later-season cultivations to control these weeds, or a successful control of them with pre-emergence spray application under optimum conditions. Post-emergence spray substitution for the third cultivation gave good weed control without significantly reducing the yield. Late post-emergence applications of 2,4-D and sodiumethylsulfate following three cultivations gave excellent broad-leaf weed control without affecting crop yields.

The work done on the F-2 series of experimental plots was for an evaluation of strip as compared with overall spraying in addition to the other rate comparisons done earlier. The extremely heavy rainfall just prior to planting and its delay of the planting date acted to produce a typical corn-weed competition problem. Weeds were not controlled when two substitutions of spray for cultivations were made. Pre-emergence sprays were not in themselves sufficient. In those plots where either of these attempts were made weeds grew vigorously and corn plants were light colored and stunted. There was no significant difference in yield between the strip (s) and overall (o) methods of spray application although subjective observations noted what was thought to be a more efficient control of weeds during the growing season by the strip method supplemented with cultivations.

Competition Field Experiments

1951 Experiments

The control of weeds was the chief factor in yield determination of the Ash Avenue experiments. The yields of plots constituting the high yielding class (Table 11) on which complete weed control was achieved by hand-weeding fell within a range of five (71.6-76.5) bushels per acre. This range is less than one-half of the least significant difference value (Table 12) of 10.37 bushels per acre. The plant heights and leaf number of this class fall within a similarly narrow range (Table 13). This set of treatments significantly increased leaf number and yield over the middle class but the plant heights are not significantly greater than those of the middle class.

The middle class contains the two and three cultivation treatments. The weeds present on these plots were 944 and 591 pounds per acre. The corn yields of these two plots (56.4 and 54.0 bushels per acre) fell between those of the high and low yielding classes but were separated from them by values greater than the value of the least significant difference. The plant height was slightly but not significantly lower but the leaf number was significantly lower than that of the high yielding class. The middle class ranked significantly above the low yielding class in all three measurements.

In the low yielding class the reduction in corn yield, plant height and leaf number were all statistically significant on reduction of the cultivations to one. The weed yield had nearly doubled, yielding 1804 pounds per acre. The increased competition caused by complete omission of cultivation and production of 2286 pounds of weeds, reduced the corn yield to 13.4 bushels per acre and produced a significant reduction in plant height to 70.4 inches.

In this experiment the correlation coefficients between yields and heights, yields and numbers of leaves, and heights and numbers of leaves were all very high (0.96, 0.97 and 0.99 respectively). The development of the corn plants seemed to have a close relationship to yield. The presence of weeds rather than lack of cultivation accounted for reductions in growth and yield of the corn.

As the weed yield increased the corn fell off proportionately in height and yield produced. The slight lowering in numbers of leaves and especially their reduced exposure to light with decreases in plant height was proportional to yield reductions as the weeds increased in size and numbers. This is especially important (6) when weeds get a head start, as was the case in field D in 1951 when rainfall interfered with seed-bed preparation.

1952 Experiments

The work at Ash Avenue in 1951 pointed up the injurious effect which weed competitors have on corn plants and it was deemed advisable to expand this phase of the experimentation in 1952 to continue the investigation of the injurious effects of different amounts of weeds on the yield. The degrees of control by different numbers of cultivations as well as hand-weeding without cultivation were repeated. Spray treatments were substituted for some of these cultivations as in the 1950-51 experiments. The result was a set of yield data with finer variations in the yields and in the degree of weed control. The 7.6 bushels per acre of the least significant difference value is found only between the lowest class and the lowest ranking member of the middle class and between no other two treatments (Table 22).

The several treatments which produced yields that were included in a high yielding class showed the near equal effectiveness of these several methods in that the least significant difference was not exceeded by the difference in yield between any of the treatments in this class. Two cultivations or no cultivation with hand-weeding fell in the high yielding class, probably indicating adequate porosity of the soil and the fact that the moisture was concentrated early in the growing season so that surface loss as well as surface root development and surface root destruction were again relatively unimportant to the production of yield. Two cultivations with pre-emergence and lay-by spray applications, two cultivations with a single pre-emergence spray application and one cultivation with hand-weeding followed the two treatments above to complete this high yielding class.

The middle class was made up of the close and distant shovel treatments, each applied three times, together with the two and three cultivation treatments without supplements. The difference between yields obtained with close and distant shovel treatments amounted to six bushels per acre. The three cultivation treatment yielded 11 bushels per acre more than the two cultivation treatment. The no cultivation treatment plot and only member of the low yielding class was more than 30 bushels below all of the other treatments.

The significant difference between the two and three cultivation treatments with the greater amount of cultivation producing the greater yield during this growing season indicated that some factor in the competition complex became critical at a lower level of weed infestation than had been the case during the 1951 growing season. The two cultivation treatment omitted the first cultivation during this growing season, whereas it had omitted the second one in the 1951 experiments. In the two cultivation treatments the weed yields showed an increase in 1952 to 2335 pounds over 943 pounds in 1951. There was no yield depression in 1951 but a significant, 11 bushel per acre, depression in 1952. This would seem to indicate a closer relationship between quantity of weeds and yield than between number of cultivations and yield. In 1952 the omission of the first cultivation resulted in the weeds gaining an advantage at an early date.

The fact that the hand-weeded and spray treatments which ahieved the greatest weed control of all treatments showed the greatest corn yields indicates the importance of controlling the weed population by whatever means. The substitution of hand-weeding or spray treatments for various numbers of cultivations, emphasizes this fact. The partial weed control effected by cultivation with the inside shovels removed and with the outside shovels removed places these treatments as slightly less effective in weed control and in corn production than the three full cultivation treatment. The two cultivation treatment permitted the development of more weeds which caused marked reduction in corn yield. The root disturbance seemed to have little if any effect.

Grass vs Broad-leaf Weed Competition Studies

1953 Experiments

These studies compared primarily the effectiveness of grass and that of broad-leaf species in depressing the growth and yield of corn. The weed plots were set up and maintained at high rates of infestation and the results show differences which are very marked, as compared with smaller but significant differences found in the previous experiments.

The grass, foxtail, proved to be the strongest competitor, present at the rate of 4692 pounds per acre and depressing the corn yield from the 111.9 bushels per acre on adjacent control plots to 9.8 bushels per acre. The mixture of the two weed species at the rate of 4276 pounds per acre caused a similar depression from 97.4 to 15.8 bushels per acre. The plots with 3954 pounds per acre of pigweed alone as a competitor showed reduction from a 100.3 bushels per acre control to 31.8 bushels per acre. In addition to the effects on yields discussed above, the weeds produced a slowing of the growth rate as expressed in both plant height and basal diameter.

The stalk-ear ratio increased markedly from 0.43 in the control plots to 0.59 in the pigweed plots, 1.42 in the mixed weed plots and 2.44 in the foxtail plots. The presence of weeds (competitors) in the various corn fields resulted in depressions of the corn yield in a direct relation to the weed yields. Staniforth (22) found that the rate of weed infestation and the length of time the weeds competed with the corn caused wide variations in the degree of competition between weeds and corn and in the final yield of corn. This is well demonstrated in comparing the results of these experiments with the 1951-52 experiments with lighter weed infestation. Here with early establishment of the weeds and no weed control treatments, the mature weed yields were two tons per acre. The depression of corn growth gradually increased, affecting the total dry matter yield of the corn and, because of the modification in stalk-ear ratio, greatly reduced the yield of corn.

Competition Factor Experiments

Greenhouse Experiments

The greenhouse experiments were done to obtain definite information of the degree of competition between the corn and weed plants under as nearly controlled conditions as possible. By growing a single corn plant together with its competitors in a given quantity of soil it was possible to circumscribe the quantity of water and soil nutrients and prevent the effects of borders and uneven stands of competitors which so often are responsible for a great deal of variability under field conditions. Information resulting from these experiments should be of value in determining differences in competitive efficiency.

The low fertility level was apparently a limiting factor in the growth of the plants maintained at this level since they used nearly the same amount of water in the course of the experiment whether the water was maintained at the high or low level. The application of nitrogen has been found to counteract the depressive effect of weed competition in the field (12) but this was no doubt under conditions in which water was not limiting and could support the crop as well as the weeds competing with it. Phosphorous additions to fulfill the weed requirements have been found to encourage the weeds more than the crop and actually depress the crop yield (23). In the greenhouse experiment the low water level also seemed to be a limiting factor, since the addition of fertilizer produced no additional growth at this water level but did produce additional growth when the water level was raised (Figure 17).

The weed levels evidenced their effects on the corn plants also in that the corn showed a greater response to increased water supply with the light weed infestations than with the heavy infestations. The two weed species also showed differences in degree of influence on the corn growth. Foxtail caused a greater reduction of corn plant yield than did velvet-leaf at any given moisture and fertility level and the weed yields varied in the same direction (Figure 17).

The photographs of the various series at the termination of the greenhouse experiments may be utilized to illustrate the discussion on the interaction of direct factors in corn-weed competition. Examination of corn plants at the four moisture-fertility level combinations (Figure 19) shows a slightly larger plant at the high than at the low moisture level under the low fertility treatment. However, under the high fertility treatment the high moisture level produced a considerably larger plant than did the low moisture level.

The overall effect of moisture on growth is indicated by a comparison of the low moisture series of Figure 22 with the high moisture series of Figure 23. The upper photograph of each figure is at the high weed infestation rate and the lower one at the low infestation rate. In each photograph the two crocks on the left were maintained at the low fertility and the two on the right at the high fertility level. In the low moisture series (Figure 22) we see that at the high infestation rate the addition of fertilizer resulted in added growth of the weeds but slightly depressed the corn plant growth whereas at the low infestation rate the added fertilizer resulted in greater growth of the corn as well as the weeds. In the high moisture series (Figure 23) the contrast between corn plant size at low fertility on the left and at high fertility on the right is less marked at the low infestation rate (lower photograph) than at the high infestation rate (upper photograph). It was evident also that the growth of all of the plants was greater in this high moisture series and that the corn leaves were darker green and larger.

The foxtail (Figure 24) and velvet-leaf (Figure 25) series consist of low fertility treatments above and high fertility treatments below in each figure. The crocks appearing on the left half of each photograph were kept at the low and those on the right half at the high moisture level. The crock on the left of each of these treatments is infested at the low rate and the one on the right at the high rate. The competition at the high fertility, high infestation rate of foxtail seems to have caused the greater suppression of corn growth at the low moisture level. In this instance moisture was limiting.

The comparison of the two species of weeds at the low infestation rate

(Figure 26) shows little visual difference between the two weed species. However, at the high rate of infestation (Figure 27) foxtail shows quite definitely to have caused a greater suppression of growth of the corn than did velvet-leaf. This is especially true in the cases where the water level was high. This relationship would not necessarily apply in the field because of the variations in available soil moisture at different levels.

SUMMARY

1. Research on the ecological phases of corn-weed competition was started on the plots of the weed control project of the Iowa Agricultural Experiment Station in 1950. The application of three normal cultivations produced the highest yield among the experimental treatments. The substitution of pre-emergence spray treatment for the first cultivation resulted in little or no reduction in yield. Substitution of spray treatment entirely for cultivation lowered the yields markedly.

2. A repetition of the 1950 experiments in 1951 was modified somewhat by abnormally heavy rainfall which resulted in poor preparation of the seed-bed and late planting. The result was poorer plant development and decreased yields. Adequate spray treatments were more effective than those treatments based on three cultivations.

3. In addition to the two-year series above, an experiment was carried out in 1951 in which the treatment plots were subdivided and the spray applied overall on one sub-plot and to a strip immediately adjacent to the plant row on the other. The treatments which had received three cultivations, produced higher yields than those receiving less than three cultivations. With one exception these also had pre-emergence spray treatments. There was no significant difference between the yields obtained from the plots to which spray was applied by the strip and overall methods.

4. The effectiveness of weed control with and without cultivation

was investigated on smaller plots in 1951. The average corn yield of the hand-weeded plots was 50 per cent greater than that of the unweeded plots. There was no significant difference in yield among the weeded plots which had received one, two and three cultivations. In the unweeded plots corn yields decreased in direct proportion to the amount of weeds left on the plots by various numbers of cultivations.

5. The 1952 work expanded the 1951 study to include investigation of the possible effects of root injury and the effectiveness of chemical weed control methods in addition to the hand and machine removal methods previously investigated. The fact that the hand-weeded and spray treatments which achieved the greatest weed control of all treatments showed the greatest corn yields indicates the importance of controlling the weed population by whatever means. The substitution of hand-weeding or spray treatments for various numbers of cultivations, emphasizes this fact. The partial weed control effected by cultivation with the inside shovels removed and with the outside shovels removed caused these treatments to be slightly less effective in weed control and in corn production than treatments with three full cultivations. Weed control seems to be of more importance in determining yield than whatever amount of root injury was caused by the inside shovels. Reduction of cultivations to two with no hand-weeding, permitted the development of more weeds which caused reduction in corn yield.

6. Early season weed control was by far the most important aspect in terms of prevention of weed establishment and its effects on corn yields. Removal of weeds at progressive stages of corn development produced

proportionately more reduction in yield caused by the weeds.

7. Heavy infestations of annual grass, foxtail, and broad-leaf weeds, pigweed, were compared as corn competitors. Foxtail caused the greatest yield reduction from 111.9 bushels per acre in control plots to 9.8 bushels per acre in adjacent experimental plots. In pigweed infested plots yield was reduced from 100.3 to 31.8 bushels. Mixtures of the two weeds reduced the yield from 97.4 to 15.8 bushels.

8. Greenhouse experiments were designed to make a more precise evaluation of factors affecting weed competition with corn. Grass and broad-leaf weeds were established in the corn at two levels, five weed plants and 20 weed plants per corn plant. The other factors investigated, water and soil fertility, were each maintained at a high and a low level in all possible combinations.

9. The differences between the two weed infestation levels, the two moisture levels and the two fertility levels were statistically significant in both the corn and weed yields produced (Table 25). The effectiveness of the grass weed, foxtail, in competing with corn was found to be greater than that of the broad-leaf weed, velvet-leaf, under all treatments.

10. In the low fertility-low moisture combinations it was difficult to ascertain which factor had become limiting first, but with increase of moisture alone to the higher level, there was an increase in yield of dry matter, whereas with increase of fertility alone to the higher level, there was no significant increase in yield.

11. In comparing the growth at two moisture levels at high fertility level it was found that there was greater growth at the high than at the

low moisture level, indicating its limiting effect in this case.

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ACKNOWLEDGMENTS

Sincere appreciation is expressed to Dr. J. M. Aikman who outlined the problem and gave direction to the experimental work as well as in the preparation of the manuscript; to Dr. W. E. Loomis for assistance in the planning and direction of certain experiments; to Dr. D. W. Staniforth for technical advice on various herbicide treatments; to Mr. W. G. Lovely for permission to use the weed control machinery experiments; and to Dr. E. F. Lind for assistance in the experimental work and in the preparation of the manuscript.

APPENDIX

Table 16. Plant heights, basal diameters and leaf numbers; grain and weed yields. Agricultural Engineering Farm, field D-2, 1950. For description of treatments see list of abbreviations, p. iv.

	Growth measurements							
	Heights (in.)		Basal diameters (16ths in.)		No. of leaves		Yields	
Treatments	Aug. 8	Sept. 14	Aug. 8	Sept. 14	Aug. 8	Sept. 14	Weeds (lbs)	Corn (bu/A)
a	103	102	15.7	15.3	13.4	11.6	568	75.3
b	91	102	14.9	14.8	13.3	11.5	843	65.4
c	101	99	15.0	14.8	13.3	12.1	189	68.7
d	90	91	14.4	14.0	13.3	11.4	1725	68.0
e	89	89	15.4	15.0	13.8	12.1	549	60.2
f	89	101	14.1	14.4	13.4	11.3	1058	61.8
g	89	90	14.4	14.3	12.8	12.2	1137	58.9
h	92	88	14.9	14.3	13.6	12.0	647	59.4
j	89	100	14.6	14.8	13.2	11.5	386	66.6
k	90	101	14.8	14.7	13.4	11.4	608	73.1
l	98	101	14.7	14.7	13.4	11.3	39	67.7
m	90	100	14.7	14.5	13.2	11.5	584	68.1

Table 17. Plant heights, basal diameters and leaf numbers; grain and weed yields. Agricultural Engineering Farm, field D, 1951. For description of treatments see list of abbreviations, p. iv.

	Growth measurements							
	Heights (in.)		Basal diameters (16ths in.)		No. of leaves		Yields	
Treat-ments	July 26	Aug. 26	July 26	Aug. 26	July 26	Aug. 26	Weeds (lbs)	Corn (bu/A)
a	59	87	11.8	11.6	6.7	10.6	490	52.5
b	62	87	12.4	11.3	6.8	10.8	316	60.3
c	62	86	11.8	11.2	7.0	10.7	419	58.3
d	57	81	10.9	10.2	6.4	10.3	1088	41.9
e	63	88	12.3	11.3	7.1	10.8	480	65.4
f	61	87	11.7	10.9	6.7	10.6	850	56.1
g	59	84	11.9	11.3	6.3	10.4	919	49.2
h	53	77	10.6	10.2	6.1	10.5	793	46.3
j	60	86	11.6	10.9	6.5	10.9	1798	56.8
k	61	86	11.6	10.9	6.8	10.6	599	59.2
l	59	86	11.6	11.2	6.6	10.9	53	57.6
m	57	77	10.4	10.2	6.2	8.9	2949	28.2

Table 18. Plant heights and basal diameters for selected treatments; weed and corn yields for all treatments. Agricultural Engineering Farm, field F, 1951. For description of treatments see list of abbreviations, p. iv.

	Growth measurements							
	Heights (in.)			Basal diameters (16ths in.)			Yields	
Treat-ments	July 14	July 29	Aug. 30	July 14	July 29	Aug. 30	Weeds (lbs/A)	Corn (bu/A)
ao							834	62.4
as							906	55.8
bo							1145	55.2
bs							694	59.0
co							736	36.8
cs							969	37.3
do	44.9	65.9	82.2	10.2	10.6	10.2	658	22.7
ds							775	21.0
eo							657	58.0
es	43.9	72.1	92.6	10.6	12.1	11.8	918	59.4
fo							989	58.0
fs							755	53.6
go							885	56.4
gs							621	43.7
ho							699	28.2
hs							653	21.5
jo	40.2	68.1	91.2	10.1	11.9	11.6	880	55.7
js							744	56.3
ko							840	66.7
ks							868	54.8

Table 19. Corn growth rates for three representative treatments. Ash Avenue Botany Research Farm, 1951. For description of treatments see list of abbreviations, p. iv.

Dates	Plant heights in inches		
	3-W	2-UW	0-UW
June 15	13.0	12.9	12.8
June 23	24.7	24.7	23.6
July 4	37.8	38.0	33.6
July 14	51.3	50.0	43.1
July 22	67.4	64.0	52.1
July 29	87.4	81.4	62.0
August 7	96.5	91.0	68.7
August 18	98.3	93.4	71.3
Sept. 4	97.5	93.1	70.7
Sept. 20	97.5	93.1	70.7

Table 20. Maximum corn plant heights. Ash Avenue Botany Research Farm, 1952. For description of treatments see list of abbreviations, p. iv.

Treatments	Heights (in.)
0-UW	88.4
2-UW	86.2
3E-UW	91.2
3F-UW	90.7
3-UW	90.6
2-S	87.6
1-W	94.2
3-W	93.9
2-W	90.8
2-SS	88.4
0-W	95.3
2-W	94.1

Table 21. Growth rates and corn yields for three representative treatments. Ash Avenue Botany Research Farm, 1952. For description of treatments see list of abbreviations, p. iv.

Dates	Treatments 2-SS	3F-UW	0-UW
		Plant height (in.)	
June 26	22.3	21.2	21.8
July 9	44.0	43.5	44.5
July 23	71.8	72.1	69.0
August 4	87.6	89.5	85.7
August 18	88.4	90.7	88.4
		Corn yield (bu/A)	
	77.6	63.8	25.5

Table 22. Stalk, grain and weed yields under various weed control treatments. Ash Avenue Botany Research Farm, 1952. For description of treatments see list of abbreviations, p. iv.

Treatment	Grain (bu/A)	Stalks (lbs/A)	Weeds (lbs/A)
0-UW	25.5	2428	6396
2-UW	57.3	1652	2336
3E-UW	57.8	2580	1701
3F-UW	63.8	2623	3662
3-UW	68.0	3604	178
1-W	73.7	2557	
2-S	74.1	2221	975
2-W	75.4	2178	
3-W	76.3	3049	
2-SS	77.6	2308	1105
0-W	80.4	3103	
2-W	81.4	3514	

Table 23. Corn plant heights from grass vs. broad-leaf competition studies. Dows, Iowa Farm, 1953. For description of treatments see list of abbreviations, p. iv.

	Dates of measurement					
Plants	June 30	July 11	July 20	July 27	August 4	August 11
C	34.9	50.3	72.4	85.3	91.8	92.4
C-P	26.8	39.0	52.4	63.8	70.2	71.8
C	33.4	47.7	80.6	89.0	98.4	99.0
C-P	29.2	41.2	58.0	66.2	76.8	80.1
C	41.5	55.9	77.8	90.1	98.6	99.2
C-P	35.0	41.9	55.6	61.7	75.1	77.6
C	40.9	60.1	85.0	96.1	104.8	104.5
C-M	31.9	43.9	62.3	70.4	82.3	87.3
C	40.7	56.6	80.0	93.1	96.6	97.0
C-M	36.3	44.3	52.8	59.8	68.5	71.3
C	41.7	56.8	76.8	91.1	96.6	97.4
C-M	38.0	45.2	51.0	54.5	64.7	65.7
C	39.3	57.4	80.1	93.7	102.1	102.1
C-F	33.0	43.6	57.4	64.6	77.6	79.6
C	39.0	55.9	80.7	95.4	103.6	104.7
C-F	23.8	31.4	41.6	52.1	50.7	60.7
C	41.0	58.0	81.1	95.2	105.0	104.6
C-F	36.6	46.6	58.4	65.0	76.8	76.9

Table 24. Volume of water used and dry weights of both corn and weed material obtained. Greenhouse experiments, 1953-4. For description of treatments see list of abbreviations, p. iv.

Factor	Treatment	Plant mixtures C	a	s	A	S
Water used	$F_1\ W_1$	4089	4102	4735	5207	5420
	$F_2\ W_1$	4066	4159	4711	5141	5229
	$F_1\ W_2$	6673	7984	7601	8660	8339
	$F_2\ W_2$	6685	8095	7624	8689	8809
Corn yield	$F_1\ W_1$	10.1	5.1	6.2	3.7	3.3
	$F_2\ W_1$	12.4	6.0	6.6	3.6	2.8
	$F_1\ W_2$	12.8	10.2	7.7	5.9	5.2
	$F_2\ W_2$	20.5	15.9	12.0	8.6	6.3
Weed yield	$F_1\ W_1$		2.9	6.2	5.3	10.2
	$F_2\ W_1$		2.4	7.0	5.9	12.5
	$F_1\ W_2$		4.6	9.6	7.6	11.8
	$F_2\ W_2$		7.7	9.8	10.4	16.9

Table 25. Analyses of variance of corn and weed yield data. Greenhouse experiment, 1953-4

Source		d. f.	M. S.	F
			Corn yields	
Replicates		4	6.095	1.37
Fertility-water levels		3	250.170	56.29**
Error I		12	4.444	
Sub-total		19		
Weed infestations		4	282.365	61.49**
Aa vs Ss	1		25.8	5.62*
A vs a	1		13.2	2.87
S vs s	1		140.5	30.60**
F x W		12	12.573	2.74
Error II		64	4.592	
Total		99		
			Weed yields	
Replicates		4	0.298	0.07
Fertility-water levels		3	99.160	23.58**
Error I		12	4.206	
Sub-total		19		
Weed infestations		3	244.923	49.51**
Ss vs Aa	1		430.9	87.10**
A vs a	1		84.2	17.02**
S vs s	1		219.6	44.39**
F x W		9	4.480	3.16*
Error II		48	4.947	
Total		79		

*Significant at 5% level.
**Significant at 1% level.